DOCUMENT RESUME

ED 207 852 SE 035 731

TITLE	NASA's Role in Aeronautics: A Workshop. Volume I--Summary.
INSTITUTION	National Academy of Sciences - National Research Council, Washington, D.C. Assembly of Engineering.
SPONS AGENCY	National Aeronautics and Space Administration, Washington, D.C.
PUB DATE	81
CONTRACT	NASA-NASW-2342
NOTE	68p.
AVAILABLE FROM	Aeronautics and Space Engineering Board, National Research Council, 2101 Constitution Ave., N.W., Washington, DC 20418 (no price quoted).
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	*Aerospace Education; *Aerospace Industry; *Aerospace Technology; Aviation Technology; Engineering Education; Higher Education; Science Education; Space Sciences; *Workshops
IDENTIFIERS	*Aviation Education

ABSTRACT

The central task of the workshop summarized in this report was to examine the relationship of the National Aeronautics and Space Administration's (NASA's) aeronautical research capabilities to the state of U.S. aviation and to make recommendations about NASA's future roles in aeronautics. Topics include NASA's role in: (1) aeronautics research and technology; (2) military aeronautics; (3) transport aircraft aeronautics; (4) general aviation aeronautics; (5) rotocraft aeronautics; (6) engineering education; and (7) information dissemination. The evoluation of NASA and its relationship with other institutions are included in the appendices. (DS)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

NRC NAS NAE IOM

ED207852

NASA'S ROLE IN AERONAUTICS: A Workshop

Volume I Summary

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

X This document has been reproduced as received from the person or organization originating it.

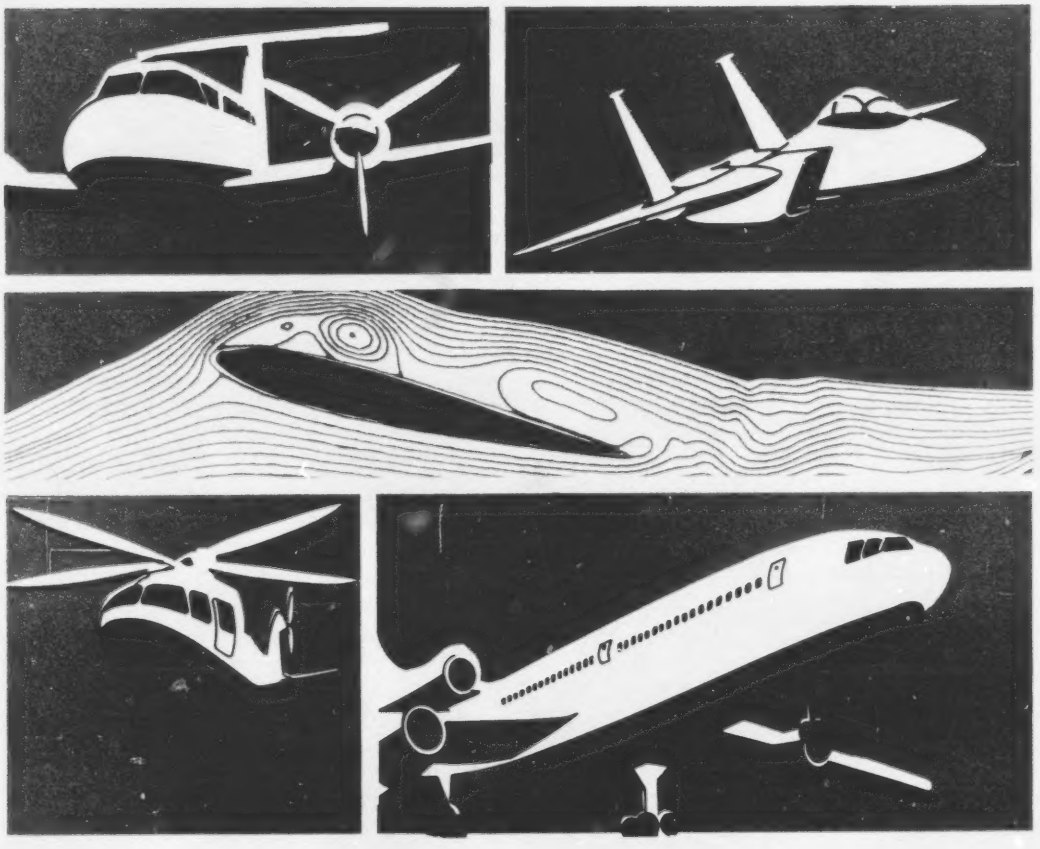
☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

SE 035 781

NASA'S ROLE IN AERONAUTICS: A Workshop

Volume I Summary



Report of a Workshop
Aeronautics and Space Engineering Board
Assembly of Engineering
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1981

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy under the authority of its congressional charter of 1863, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

This report and the study on which it is based were supported by Contract No. NASW-2342 between the National Aeronautics and Space Administration and the National Academy of Sciences.

Copies of this publication are available from:

Aeronautics and Space Engineering Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

IN MEMORIAM

As this report was nearing completion in October 1980, the workshop participants were saddened by the death of Malcolm S. Harned, Chairman of the Panel on General Aviation Aircraft, a distinguished colleague and a major contributor to their deliberations and conclusions.

January 16, 1981

Mr. Robert W. Rummel, Chairman
Aeronautics and Space Engineering Board
National Research Council
Washington, D. C. 20418

Dear Mr. Rummel:

It is my privilege to submit the report of the "Workshop on the Role of NASA in Aeronautics" which was conducted during the period July 27 to August 2, 1980, at the National Academy of Sciences Study Center, Woods Hole, Massachusetts.

The purpose of the workshop was to determine NASA's future role in aeronautics. In pursuit of this objective, 60 experts were organized into five panels for what turned out to be an arduous and exhilarating week-long effort to weigh the available information and arguments and to develop the conclusions and recommendations that are presented in this report.

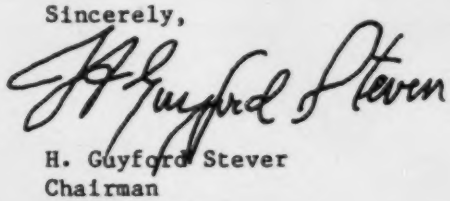
The message of the workshop is centered in three overriding conclusions:

- The close and successful working relationship that was initiated in 1915 between the National Advisory Committee for Aeronautics (NACA) and the fledgling aviation industry and has continued uninterrupted to its present mature state under the National Aeronautics and Space Administration must be maintained and strengthened. The present relationship is unique in the United States and stands as an example of effective cooperation between government and industry, which is particularly important in light of the current concern with developing a cooperative and supportive relationship between government and industry. Contrary to a view widely held by many sectors of private industry that there should be little or no government involvement in their affairs, the various sectors of the aviation industry that were represented at the workshop clearly endorsed the continuation of the present NASA-industry working relationship. In fact, two sectors, general aviation and rotorcraft, argued for a larger NASA role in support of research in their fields. The key point here is that government cooperation--as exemplified by the NASA-aviation industry relationship--can have a stimulating and strengthening effect on an industry that will enable it to compete more effectively in the international marketplace and prevent its vulnerability to foreign trade offensives.

- With regard to the fundamental question that the workshop was asked to address, there was unanimous agreement by the participants that NASA should be engaged fully in the first four roles described in Section IV--that is, National Facilities & Expertise, Research, Generic Technology Evolution, and Vehicle Class Technology Evolution. Moreover, there was consensus that NASA should be involved in two additional roles -- Technology Demonstration and Technology Validation--when, after an assessment of each individual case, the potential benefit to the country is considered great. With the exception of the Panel on General Aviation, the panels agreed that under very special circumstances NASA also could have a role in Prototype Development and Operations Feasibility. Apart from these specific roles, the workshop participants identified the following possible new ones for NASA: providing a technical data base for the Federal Aviation Administration to use in aircraft airworthiness certification; contributing to the solution of the problem of decreasing numbers of graduate students in aeronautical science and engineering; and disseminating information on foreign aeronautical research and technology to U.S. users.

- Finally, because of the economic, social, political, and technological challenges perceived to be currently threatening the U.S. leadership in aeronautics, the aviation community represented at the ASEB workshop concluded that there is an urgent need for a clear and emphatic statement to reaffirm, clarify and strengthen NASA's role in aeronautics. This is important to enable NASA to fully and successfully sustain its mission as mandated by the National Aeronautics and Space Act of 1958. Indeed, such a statement should be part of a broad commitment to a strong national policy for aeronautics.

Sincerely,



H. Guyford Stever
Chairman
ASEB Workshop

AERONAUTICS AND SPACE ENGINEERING BOARD

Robert W. Rummel, CHAIRMAN
Robert W. Rummel Associates, Inc.

Robert A. Fuhrman, VICE CHAIRMAN
President
Lockheed Missiles and Space Co., Inc.

Neil A. Armstrong
Chairman of the Board
Cardwell International, Ltd.

Holt Ashley
Professor, Dept. of Aeronautics/
Astronautics & Mechanical
Engineering
Stanford University

Richard E. Black
Director, Technologies
Douglas Aircraft Company

B. Paul Blasingame
Retired Manager
Santa Barbara Operations
Delco Electronics Division
General Motors Corporation

John G. Borger
Retired Vice President,
Engineering
Pan American World Airways

Edward S. Carter
Director of Technology
Sikorsky Aircraft Division
United Technologies Corporation

Richard J. Coar
Executive Vice President
Power Group
United Technologies Corporation

Robert R. Gilruth
Retired Director
Lyndon B. Johnson Space Center
National Aeronautics and Space
Administration

Grant L. Hansen
President, The Systems Group
System Development Corporation

Ira Grant Hedrick
Senior Vice President and
Presidential Assistant for
Corporate Technology
Grumman Aerospace Corporation

Klaus P. Heiss
President
ECON, Inc.

Jack L. Kerrebrock
R.C. MacLaurin Professor and
Head, Dept. of Aeronautics and
Astronautics
Massachusetts Institute of
Technology

Hans W. Liepmann
Director, Graduate Aeronautical
Laboratories
California Institute of Technology

James W. Mar
Jerome C. Hunsaker Professor
of Aerospace Education
Department of Aeronautics
and Astronautics
Massachusetts Institute
of Technology

Robert B. Ormsby, Jr.
President
Lockheed-Georgia Company

George S. Schairer
Consultant
The Boeing Company

A. Richard Seebass
Department of Aerospace and
Mechanical Engineering
University of Arizona

Gordon Sim
Vice President
Program Management
Rohr Industries, Incorporated

R. Dixon Speas
President
Aviation Consulting
Incorporated

John E. Steiner
Vice President, Corporate
Product Development
The Boeing Company

Robin H.H. Wilson
Senior Vice President
Operations
Trans World Airlines
Incorporated

Edward Woll
Retired Vice President
Project and Technology
Assessment Group
General Electric Company

Executive Staff

Robert J. Burger, Executive Director

John Peter Taylor, Assistant Director

Albert J. Evans, Professional Associate

Jean M. Fougstedt, Administrative Assistant

Marlene R. Veach, Administrative Secretary

Laura D' Sa, Administrative Secretary

PREFACE

Aeronautics is changing in many significant respects. The implications of this are so far-reaching as to call into question the future position of the United States in world aviation.

The magnitude of this question, with its possible consequences for the nation's economy and security, led the National Aeronautics and Space Administration (NASA) to seek an independent evaluation from the Aeronautics and Space Engineering Board (ASEB) of the National Research Council's Assembly of Engineering. Specifically, the ASEB was asked to assess the nature and implications of the current state of U.S. aviation in a world setting and their significance for NASA's role in the nation's aeronautical future.

The ASEB responded by convening a workshop July 27 through August 2, 1980, at the National Academy of Sciences' Woods Hole Study Center. The workshop was structured into four panels covering military aviation, transport aircraft, general aviation, and rotorcraft. In addition, an overview panel was formed to consider NASA's role in research as well as its relationships with other elements of the aeronautics community.

The central task of the workshop was to examine the relationship of NASA's aeronautical research capabilities to the state of U.S. aviation and to make recommendations about NASA's future roles in aeronautics.

NASA and its predecessor, the National Advisory Committee for Aeronautics (NACA), traditionally have maintained a cooperative relationship with the aeronautical industry, with other government agencies concerned with aircraft operations and regulations, and with the academic community engaged in aerospace research. This triumvirate was taken into account in planning the workshop and selecting the participants. Thus, representatives from each part of the aeronautical community were invited, and information on NASA's relationship with each was the subject of special presentations prior to the working sessions. Representation from industry was predominant because industry's relationship with NASA is considered to be a key element in examining the present and future roles of NASA.

The members of the workshop panels represented, in total expertise and experience, all of the important sectors of aeronautics: military aircraft and missiles; commercial air transports; general aviation;

rotorcraft; university and private research; airline operations; and government regulatory agencies. In addition, the participants also included representatives of other industries--notably, automotive, electronics, and steel. Including the speakers and other non-panel members, close to 80 individuals participated.

The participants were asked to address the issue of NASA's role in the context of a wider discussion concerning: the status and dimensions of U.S. aeronautics; the key aeronautical problems and opportunities that are likely to be amenable to research and technology development; the historical evolution and accomplishments of NASA in aeronautical research and technology development; and possible alternatives to NASA. Each of these subjects is discussed thoroughly in separate panel reports and are summarized in this document, which also contains the conclusions and recommendations of the workshop.

The report of the workshop consists of seven volumes:

I -- Summary

II -- Report of the Panel on Military Aviation

III -- Report of the Panel on Transport Aircraft

IV -- Report of the Panel on General Aviation

V -- Report of the Panel on Rotorcraft

VI -- Report of the Overview Panel on Aeronautical Research

VII -- Background Papers--The Outlook for Aeronautics and Relevant Areas

In order to help focus the discussion, NASA officials developed and provided a concise set of definitions of eight possible roles for NASA: National Facilities and Expertise; Research; Generic Technology Evolution; Vehicle Class Technology Evolution; Technology Demonstration; Technology Validation; Prototype Development; and, Operations Feasibility. Because some of these roles differ, depending on the aeronautical discipline involved, the roles are assessed within six principal aeronautical disciplines: aerodynamics, structures and materials, propulsion, electronics and avionics, vehicle operations, and human engineering. Definitions of these roles and disciplines are contained in Section IV of Volume I. The matching of the roles and disciplines is treated in Volumes II-VI and summarized in Section II of Volume I.

The workshop participants were extensively briefed by officials from NASA, the Department of Defense (DOD), and the Federal Aviation Administration (FAA), by leaders from the aviation manufacturing and operating industries, and by a member of Congress. The briefings are to be found in Volume VII.

Each panel separately considered the national benefits produced within the dimensions of its sector and the relative state of the

sector's world position; each considered the evolution of NASA's role, as well as a rationale for NASA's aeronautical support of its sector; and, finally, each panel produced sector-oriented conclusions and recommendations for NASA's roles for the future. Although there are obvious overlaps, the similarities and differences in each of the panels' findings are preserved in the separate reports of the sector-oriented panels, Volumes II-V.

An Overview Panel considered the fundamental relationships among NASA, other government agencies, the private sector, and academe. The Overview Panels report on aeronautical research is Volume VI.

Completing the Summary, Volume I, are four Appendixes--two of which are the "Evolution of NACA/NASA in Aeronautics" (Appendix A) and "NASA's Institutional Relationships" (Appendix B). Appendix C is a "Bibliography" and Appendix D lists the "Workshop Panels' Membership."

The workshop report does not pretend to be a complete study of all facets of aeronautical policy for the United States. In dealing with many of the assigned tasks, however, it was necessary to use as a basis for discussion either stated, "de facto" or evident national policies. It is believed that the conclusions in this report should receive serious consideration in the formation of a coherent national aeronautical policy.

NASA'S ROLE IN AERONAUTICS

VOLUME I

SUMMARY

CONTENTS

I	A VIEW OF THE U.S. AERONAUTICAL COMMUNITY	1
	STATE OF U.S. AERONAUTICS INDUSTRY	1
	SIGNIFICANT CHANGES	2
	NASA's RESEARCH ROLE--PAST AND PRESENT	5
	ALTERNATIVES TO NASA	6
II	NASA'S FUTURE IN AERONAUTICS	7
	NASA'S ROLE IN AERONAUTICS RESEARCH AND TECHNOLOGY DEVELOPMENT	7
	NASA'S ROLE IN MILITARY AERONAUTICS	9
	NASA'S ROLE IN TRANSPORT AIRCRAFT AERONAUTICS	11
	NASA'S ROLE IN GENERAL AVIATION AERONAUTICS	13
	NASA'S ROLE IN ROTORCRAFT AERONAUTICS	14
	NASA'S ROLE IN ENGINEERING EDUCATION	16
	NASA'S ROLE IN INFORMATION DISSEMINATION	17
	NASA'S ROLE WITH OTHER ORGANIZATIONS	18
	CURRENT AND FUTURE PROBLEM AREAS	18
III	SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS	21
IV	DEFINITIONS OF ROLES AND DISCIPLINES	27
	ACKNOWLEDGEMENTS	31
	REFERENCES	35

APPENDIXES

A.	EVOLUTION OF NACA/NASA IN AERONAUTICS	37
B.	NASA'S INSTITUTIONAL RELATIONSHIPS	45
C.	BIBLIOGRAPHY	53
D.	WORKSHOP PANELS' MEMBERSHIP	55

I. A VIEW OF THE U.S. AERONAUTICAL COMMUNITY

Any assessment of NASA's future role in aeronautics must take cognizance of the current and projected status of the United States in world aviation. It is also important to examine the past performance of NASA in advancing U.S. aeronautical technology to its present status and to consider whether there are alternative approaches to advancing aeronautical technology that would be preferable to those currently pursued.

State of U.S. Aeronautics Industry

The preeminence of the United States in aviation is a consequence of technological capability gained during and since World War II. One major piece of evidence for U.S. aeronautical superiority is the presence of American-made aircraft at every large airport in the free world.

All 50 states contribute to the nation's aircraft production. This involves some 10,000 companies employing about 1 million Americans. Today, aerospace is the second largest employer among U.S. manufacturing industries. It contributes more than any other manufacturing industry to the U. S. balance of trade and has recently replaced agriculture as first in net exports.

Even so, the workshop participants hold that the current statistics may be the high water mark for U.S. aviation's relative position in the world. U. S. manufacturers of commercial air transports have lost more than 20 percent of their market to European competitors over the past several years. The U.S. market share for rotorcraft has decreased by 15 percent at a time when the world rotorcraft market is expanding. The commuter airplane market is now dominated by foreign manufacturers, who are also making significant gains in the business-jet market. Last year, U.S. production of military fixed-wing aircraft and helicopters was one-half the peacetime level following the Vietnam war. These are some of the indicators that point to a change in U.S. aeronautical leadership.

Comparisons of the status of U.S. production and sales of aircraft with foreign competitors can be misleading, however. That statistics show the U.S. to be on a par with or even ahead of a competitor is

relatively meaningless if the competitor has been gaining steadily over a period of years. Such a trend could be a signal that the competition may be about to surpass the U.S.

Technical competence takes some time to develop, and the momentum that accompanies such development is substantial. A competitor can carry forward on his built-up momentum, but it is difficult to restore technical momentum in an area where the pace has slackened. Thus, there should be no comfort whatsoever in the classic statement "We're still ahead in that area" if it applies to a convergence and crossover that is prevalent in several important areas of aeronautics.

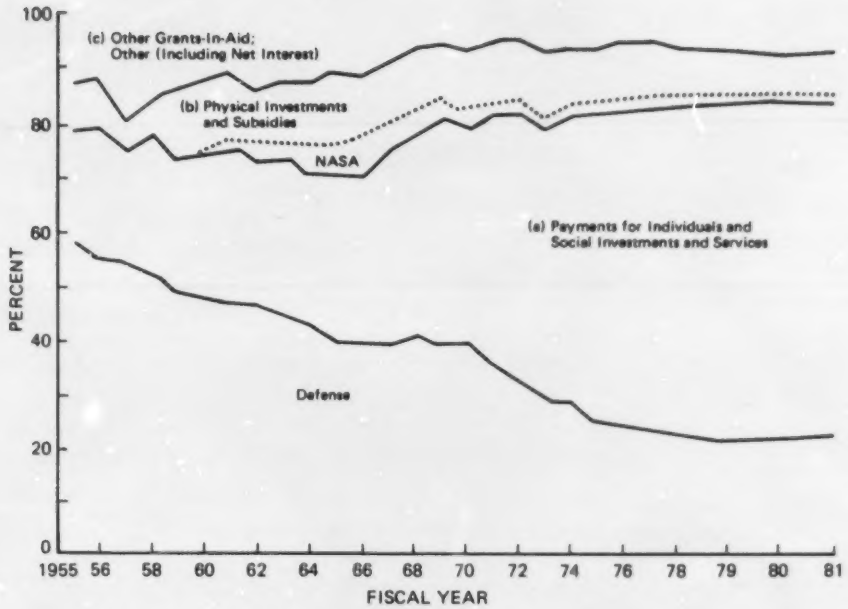
Significant Changes

The factors affecting aeronautical changes are multifaceted and are not confined solely to the United States in their scope. Such changes encompass domestic factors that have served to diminish the strength and vigor of U.S. technological capabilities. They also include changes that have occurred worldwide as other countries have become more effective competitors in the international market.

Addressing the entire body of changes and its total implications to the nation exceeded the workshop's capabilities. Nonetheless, the working panels considered it appropriate to note the progressive changes in U.S. national priorities, as reflected in the federal unified budget outlays portrayed in Figure 1. In the view of the workshop participants, such changes have had a profound effect on our relative position in aeronautical technology. Admittedly, analysis of the federal budget with regard to the allocations made each year for different purposes is a very complex issue involving much more than questions about aeronautics, such as concerns about foreign policies, world food shortages, energy needs, social well-being, and health care. Still, the effect of these changes on budget priorities was considered appropriate for review because it is one of the several perspectives considered by the panels in developing their conclusions and recommendations.

As noted in Figure 1, toward the end of the 1960s, the U.S had firmly reordered its priorities for federal outlays. This process had incremental side effects (in large measure unintended) that resulted in a contraction of the nation's research and development infrastructure--through avenues of direct federal support. Through tax policy and by expanded regulation of the private sector this has affected both the infrastructure components (academe, industry, and government) and research disciplines, all to varying degrees. However, aeronautical research and its component structures were particularly affected by a relative diversion of federal funding from the NASA and military programs. Coincident with this diversion, changes occurred worldwide, as other nations rebuilt their industrial base to become viable competitors and, indeed, to attain a larger number of leadership positions in markets formerly dominated by the United States.

Aviation has become increasingly affected in this process of change over the past decade. Recognizing the attractiveness of potential



(a) Includes retirement, disability, social security, medicare, unemployment insurance, welfare, food stamps, medicaid, low income assistance, payments for education, health, manpower training and social services, including grants-in-aid to State and local governments.
(b) Includes natural resources, environment and energy, agriculture, commerce and transportation, community and regional development; space and technology.
(c) Grants-in-aid for international affairs, law enforcement and justice, general government, revenue sharing and general-purpose fiscal assistance.

Sources: OMB; Budget of U.S. Govt., FY 78, 79, 80, 81; AIA.

FIGURE 1 Composition of Federal Unified Budget Outlays

return for its member nations from a competitive civil aircraft industry and an expanded air transportation system, the European community in 1969 conducted an extensive assessment of its aeronautical future. By 1972, the European governments had endorsed the policies and plans needed to realize this potential and to displace the U.S. from its position of leadership in aviation.[1,2] The European plans have emphasized shared national responsibilities and collaborative government and industrial programs to overcome the competitive advantages of U.S. economies of scale--most notably in human resources, in financing, and in research and technological development.

Following the European lead, Japan, Canada, Brazil, and other countries have also included civil aircraft development and production in their national industrial plans. Japan, significantly, has established aircraft at a high priority in its national industrial plans, and has

meticulously nurtured its advanced research toward civil aviation.[3,4]

As foreign countries have increased their efforts on civil aircraft manufacturing, on advanced aeronautical research, and on expansion of their airlines, the United States has continued along a path that has increasingly constrained all three.

There also are significant changes affecting the position of the United States in military aeronautics. Air power is a critical ingredient in a nation's security. If the United States is to have the military air capability necessary to defend the nation successfully, it must have the most advanced technology available, especially if the number of its aircraft and missiles is fewer than those of a potential adversary.

Today, the United States relies on the capabilities of its allies to complement its air power. Although most of the post-World War II aircraft, armament, and equipment of these allies have come from U.S. industry, the trends indicate that many reequipment items will be designed and manufactured either by individual countries or by foreign consortiums. Some foreign countries have been improving their aeronautical research capabilities during the last 15 years. Today their aggregate research facilities are comparable to those of NASA, and the resulting aircraft and missiles reflect their technology to be equivalent to U.S. designs.

Against this backdrop, the USSR continues to expand and modernize an extensive array of military airplanes, missiles, and armament. In all, the evidence points to a continuing trend of improvement of USSR air power, plus a continuation of Soviet willingness to supply modern, high-performance aircraft to Third World nations.

To meet this challenge, the U.S. military air services depend upon a strong complementary aeronautical technology base in NASA, industry, and academe to supplement their own efforts. Aeronautical technology developments by NASA are vital to the performance of the DOD's basic mission of defending the United States against any adversaries.

There is another area of significant change that was considered by the workshop participants. It is not necessary to elaborate here on the national and worldwide concern about the cost and availability of fuel. It should be noted, however, that a fundamental objective of aeronautical technology always has focused on improving efficiency. In past decades, the cost of fuel was only one of many economic factors to be balanced in the interest of improving aviation efficiency and productivity. During the 1950s and 1960s most aeronautical advances were made through improvements in speed and performance. The Arab oil embargo of 1973-1974 resulted in a significant and continuing dislocation in fuel prices. As a consequence fuel efficiency per se became a major concern of governments and the aviation industry everywhere.
The U.S. aircraft industry invested billions of dollars in activities aimed at improving efficiency, and the Congress asked NASA to launch major programs designed to increase the fuel efficiency of transport aircraft.

New technological advances in aerodynamics, in structures and materials, in electronics, and in propulsion offer the potential for

dramatic improvements in the efficiency of aircraft. Such improvements could make obsolete virtually all U.S. aircraft now in production or design. One decade from now, world leadership in aeronautics will be achieved, in all probability, by the nation or nations that seize the initiative and move such technologies from their present research status through the refinement and validation processes essential for successful production and operation of more efficient aircraft.

Considering the erosion of momentum in U.S. aeronautical technology, the opportunities during the next decade may favor a foreign competitor if this country fails to maintain and improve its technological capabilities in aeronautics.

NASA'S Research Role--Past and Present

In 1915, the U.S. Government firmly stated its objectives for aviation when it established the National Advisory Committee for Aeronautics. The original committee comprised members from academe, the military, and civil government. During its formative years, the purpose of NACA was to guide and supervise the fledgling science of aeronautics in practical military and civil applications.

Gradually, as the nation began to recognize the potential inherent in aeronautics, NACA acquired in-house capabilities that yielded much aeronautical information derived from fundamental research, flight experiments, and ground testing. These capabilities contributed significantly to the nation's understanding of the problems of flight. As World War II approached, NACA's activities were extended into propulsion research and testing. During the war years, it was the close teamwork among NACA, industry, and the military that forged a commanding position for U.S. aeronautics.

Combat experience exposed problems in new aircraft, and NACA's highest priority during wartime was to find practical solutions to such problems. The NACA's second priority was to conduct a variety of fundamental research projects aimed at meeting future defense needs. It became evident that NACA's experience in developing practical solutions to the problems confronting the military and industry, along with its independent approach to fundamental research, had created the synergism that was to spark the transition of U.S. wartime aviation supremacy into its peacetime preeminence.

The NACA-military-industry working relationships endured after the war, and until the late 1950s NACA remained a major participant in the refinement and validation of jet aircraft technology and in the basic explorations of supersonic and stratospheric flight. This post-war period was particularly productive for U.S. aeronautics.

The character and substance of U.S. aeronautical research were affected when NACA was replaced by NASA. The successor agency was organized in 1958 with an emphasis on space priorities. NASA placed more emphasis on contracting for much of its research rather than on the performance of independent research, which had characterized NACA. More important, NASA made significant diversions of aeronautical capabilities and managerial attention to space activities. Concurrently,

there was a commensurate decline in funding and manpower for aeronautics and hence a general degradation of NASA's aeronautical research capability.

Alternatives to NASA

The workshop panels reviewed the possible alternatives to NASA for conducting aeronautical research and technology development. They considered various collaborative practices for augmenting the capabilities of other organizations already engaged in aeronautical research in varying degrees, such as the aircraft manufacturers, the armed services, and the universities. None of these was thought to be wholly or even substantially a substitute for NASA. Indeed, that NASA and its predecessor NACA worked effectively and in harmony with the other aeronautical communities for two-thirds of a century was considered to be a major strength of the present arrangement.

Of necessity, in considering the alternatives to NASA, the panels also addressed the manner in which the U.S. leadership in aeronautics had been attained. It turns out that NASA has provided a central technological resource that the U.S. aircraft companies drew upon to compete against each other. Out of their competitive battles, the inefficient were eliminated and the stronger companies emerged with a collective industrial strength that has produced the superior products with which the U.S. gained its world market dominance. In fact, such domestic competition has been key in producing virtually all U.S. aircraft that have proven successful in world competition.

The panels individually noted this catalytic role of NASA and its relationship to the U.S. industry's internal competition with the end result of product superiority. The emergence of a dominant manufacturer into NASA's role or, to a lesser extent, cooperative or joint efforts between dominant manufacturers could impair the benefits derived from domestic competition.

Substantial enlargement of the Department of Defense efforts in aeronautical research and technology development might enable it to become self-sufficient. But because the needs of civil aeronautical technology often diverge substantially from military aeronautical technology, civil aviation would not be well served by this approach.

The question of separating the aeronautical capabilities from NASA and forming a new and separate government agency was not considered by the workshop panels. It was assumed that roles in research and technology development would be no different if conducted by a separate government organization or by NASA.

The workshop participants noted that following World War II all units of the aeronautical community made a strong effort to build up their aeronautical research facilities until the increasingly prohibitive expense resulting from unwarranted duplication and overlap forced change. The balance in effort among the participating members of the aeronautical community that the United States now enjoys has been forged over the decades of the 1950s, 1960s, and 1970s and has brought important benefits to the United States.

II. NASA'S FUTURE IN AERONAUTICS

NASA'S ROLE IN AERONAUTICS RESEARCH & TECHNOLOGY DEVELOPMENT

Each of the panels was asked to study in detail the proper role of NASA in its sector. NASA's possible activities: (1) acquiring and operating facilities and acquiring and maintaining expertise for aeronautical research and technology development (National Facilities and Expertise); (2) providing new knowledge in the flight sciences (Research); (3) applying this knowledge to develop technology for aircraft in general (Generic Technology Evolution) and (4) for specific vehicle classes (Vehicle Class Technology Evolution); (5) demonstrating the feasibility of new technology for application to operational vehicles (Technology Demonstration); (6) validating the readiness of new technology for use (Technology Validation); (7) designing, developing and acquiring vehicles representative of a final production item (Prototype Development); and (8) operating vehicles and systems as research projects to determine the feasibility or practicality of aircraft systems operations to meet special needs (Operations Feasibility). The matrix shown in Figure 2 was developed to assist the panels in determining how NASA's roles vary among disciplinary categories. A detailed definition of the roles and disciplines shown in the matrix is provided in Section IV.

Although the participants worked within a structure comprising five panels, certain themes and common trends resulted. There was agreement about the importance of U.S. aeronautics to the nation. NASA's most important contribution to all the fields of aeronautics has been, and will continue to be, in research and in technology development. NASA has a multi-billion dollar investment in some special, high-technology facilities and equipment. NASA also has first-class research and technical talent at work in those facilities. Both the NASA facilities and the assembled expertise represent a national resource that cannot be duplicated by industry. NASA certainly must continue to carry out responsibilities that flow from this great facilities endowment and expertise.

All the panels agreed that NASA should have a predominant role in Research and in Generic and Vehicle Class Technology Evolution. The Overview Panel noted that there had been an erosion of NASA's research

NASA ROLE CODE:
1. Major Role
*2. Moderate Role
*3. Minor Role
*– No Role

ROLES \ DISCIPLINES	AERODYNAMICS	STRUCTURES & MATERIALS	PROPULSION	ELECTRONICS & AVIONICS	VEHICLE OPERATIONS	HUMAN ENGINEERING
NATIONAL FACILITIES & EXPERTISE						
RESEARCH						
GENERIC TECHNOLOGY EVOLUTION						
VEHICLE CLASS TECHNOLOGY EVOLUTION						
TECHNOLOGY DEMONSTRATION						
TECHNOLOGY VALIDATION						
PROTOTYPE DEVELOPMENT						
OPERATIONS FEASIBILITY						

*If a proposed project or program initially falls in a recommended moderate, minor, or no-role category, but, following review of its merits on an individual case basis, is deemed to be a desirable undertaking by virtue of its being in the national interest, or mandated by the Congress or as a result of review it is concluded there are other overriding circumstances, then NASA's role for that project or program would be elevated to a major one (i.e., Category 1).

FIGURE 2 Role/Discipline Matrix

capabilities and recommended that NASA's roles in basic research be strengthened.

Research requires continuous direction of the best talent toward a more complete understanding of phenomena of concern to aeronautics. Failure to make the required investment in research will result in a depleted technology base a decade or more later. Similarly, a revitalized research effort is not likely to lead to technologically significant results being applied in less than a decade.

NASA needs to direct substantial effort to recruiting talented staff and directing them toward research careers. New ways should be sought to encourage university research directed toward aeronautics disciplines. The bridge that NASA provides from research by a government agency to the industrial application of the ensuing technology is unique in the annals of applied research in this country.

A key issue before the workshop was how far NASA should go in technology development. The participants agreed that NASA should have a predominant role in Research and Generic and Vehicle Class Technology Evolution. It was also clear that NASA should play a role in Technology Demonstration and Technology Validation in specific cases when the potential benefits to be derived from the technology are judged to be high. In some cases full-scale test or experimental flight test is

required to obtain the data needed to evaluate a concept in order to carry technology to a point where the feasibility of applying it and realizing the benefits of its use in future vehicles can be determined. This can be considered an extension of the role of technology evolution when significant technical uncertainties regarding scale-effects or interactions between components remain. Examples of such beneficial programs include new technology to reduce fuel consumption, noise, and noxious exhaust emissions. The workshop unanimously recommended that NASA undertake Technology Demonstration and Technology Validation when the potential benefits to the country are judged to be high after a careful case by case review.

One of the workshop participants from a non-aviation industry, while agreeing with the conclusion that NASA's roles in aeronautics should include Research, Technology Evolution, Technology Demonstration and Technology Validation, questioned the arguments given in support of NASA carrying aeronautical programs beyond the level of Technology Demonstration. This point is discussed further in the Report of the Panel on Transport Aircraft (Volume III).

For the foreseeable future, it is recommended that the central thrust of NASA's roles in research and technology development be in the areas of aerodynamics, propulsion, and materials and structures. In the area of electronics, however, NASA should structure its role carefully. NASA can make important contributions in the area of control systems for flight and propulsion (e.g. systems related to aerodynamic and structural active controls), but its role in communications and navigation should remain minor. It is recommended that NASA structure a strong role in the human factors area, particularly as it relates to flight safety, which is a field of overriding importance to aeronautics. Many of the technologies in which NASA has substantial expertise are related to safety, and it is recommended that NASA explore all of its roles and technical capabilities to provide a maximum contribution to the improvement of safety in aeronautics.

In each of the reports of the panels representing the different sectors of the aeronautics community, NASA's role was rated in differing ways. The panel reports, as well as a special report on NASA's role in research, appear in their entirety in Volumes II through VI. Following are summaries of each panel's recommendations for NASA's roles as they pertain to the respective sectors of the aeronautics community.

NASA'S ROLE IN MILITARY AERONAUTICS

Innovative support to the Department of Defense (DoD) has always been an important role for NASA in aeronautics. Independently and on its own initiative, NASA conducts research of use to the military. Also, with no exchange of funds, NASA conducts tests for the DoD and DoD contractors in its own facilities and assists in the analysis and interpretation of data. Such development testing activity provides the DoD with independent and objective appraisal and affords NASA first-hand knowledge of the military's needs and insight into the problems associated with the application of new and advanced technology. This

cooperative relationship, with NASA's effort conducted within its own budget allocation, without DoD financial support, permits NASA to maintain its essential independence and objectivity. The procedures for NASA's initiation, management, and oversight of such efforts are efficient, well-established, and should not be modified.

The broad spectrum of military aeronautical missions results in a multitude of technology needs. Many of these are closely related to those of civil aeronautics, such as fuel economy, efficient structures, low-drag aerodynamic shapes, short take-off and landing, durable high-performance engines, and low operation and maintenance costs. Other requirements, however, are uniquely military, such as high maneuverability for fighter aircraft, survivability against defenses, hardening against blast and radiation, and special features for carrier-based aircraft.

Figure 3 is the matrix of NASA's roles and associated disciplines in support of the aeronautical needs exemplified above. The Panel on Military Aviation considered Maintenance of National Facilities and Expertise, Basic Research, and Generic Technology Evolution in the fields of aerodynamics, structures and materials, and propulsion to be most important for NASA in providing technical support for the development of military aircraft and missiles. Essentially no role is recommended for NASA in Prototype Development and Operations Feasibility for military aircraft and missiles, except in some cases as indicated by the superscripts and the special circumstances described in the footnote of the matrix.

NASA ROLE CODE
1. Major Role
*2. Moderate Role
*3. Minor Role
*– No Role

ROLES \ DISCIPLINES	AERODYNAMICS	STRUCTURES & MATERIALS	PROPULSION	ELECTRONICS & AVIONICS	VEHICLE OPERATIONS	HUMAN ENGINEERING
NATIONAL FACILITIES & EXPERTISE	1	1	2	3	2	2
RESEARCH	1	1	1	3[e]	3	2
GENERIC TECHNOLOGY EVOLUTION	1	1	1	3[e]	3	2
VEHICLE CLASS TECHNOLOGY EVOLUTION	2[a]	2	3[d]	3[e]	3	3
TECHNOLOGY DEMONSTRATION	2	2	3[d]	3[e]	–	3
TECHNOLOGY VALIDATION	2	3[c]	3[d]	3[e]	–	–
PROTOTYPE DEVELOPMENT	3[b]	–	–	–	–	–
OPERATIONS FEASIBILITY	–	–	–	–	–	–

NOTES
(a) But Code '1' for airlift and V/STOL
(b) Extensive facility support
(c) But Code '2' for airlift and supersonic cruise
(d) But Code '2' for airlift, V/STOL, supersonic cruise, and fuel efficiency
(e) But Code '2' for flight and engine controls

*If a proposed project or program initially falls in a recommended moderate, minor, or no-role category, but, following review of its merits on an individual case basis, is deemed to be a desirable undertaking by virtue of its being in the national interest, or mandated by the Congress or as a result of review it is concluded there are other overriding circumstances, then NASA's role for that project or program would be elevated to a major one (i.e., Category 1).

FIGURE 3 MILITARY AERONAUTICS Role/Discipline Matrix

Specifically, the panel recommended that:

- o NASA's role be strengthened in the disciplines of aerodynamics, structures and materials, and propulsion. Military endorsement for this role should not be limited to currently defined needs, since perceptions of future needs are often misleading and inadequate.

- o NASA's role in support of DoD be limited in the disciplines of vehicle operations, human engineering, and that part of electronics and avionics that does not bear directly on aerodynamic, structural, or propulsion design.

- o NASA's former leadership role in the acquisition and testing of experimental aircraft to explore the frontiers of flight be restored even in the absence of apparent specific military applications. NASA's contribution to this aspect of aviation has diminished, and it is a proper role for the agency. Such initiatives should be considered on an individual basis for implementation by NASA.

- o NASA's historical supporting role and current excellent working arrangements with the DoD in aeronautics be continued in program selection, management, technical cooperation, and data exchange.

NASA'S ROLE IN TRANSPORT AIRCRAFT AERONAUTICS

The Panel on Transport Aircraft concluded that NASA's selection of technology development programs needs to involve consideration of several judgmental factors. These include: the technical difficulty, the market constraints, the capital risk involved, the gestation period involved, the societal concerns, the extent of foreign competition, and the profit potential of specific technological advances. The weight of each of these factors, when coupled with the recognition that industry resources are not available and the importance of the advancement to the nation, provide a basis for determining the extent of the role that NASA should play in a specific technological development.

The need for U.S. Government support of aeronautical research and technology development is particularly important at this time in view of the technological improvements that appear possible for the next generation of transport aircraft, and the increased momentum of foreign competitors in moving new technology into product applications. Substantial technological opportunities exist that are critically important to the future advancement of U.S. aeronautics. Assembling the body of knowledge to put such technologies into use frequently is a long-term effort. In notable cases NASA has fulfilled this vital function. It is recommended that NASA identify the most important areas of needed technology improvement and, when development time is likely to be long, assume the role of assembling a sufficient body of technical knowledge to allow the nation to make effective and timely

use of the new technologies. Development of composite primary structures and technology enabling full use of active controls are two specific examples. Successful development and utilization of these technologies could provide the basis for world leadership in aeronautics by any of the major industrial nations.

The importance of air transportation to the nation's economy, the contribution of transport aircraft manufacturing to the balance of trade, and the increase in foreign government-supported competition led the panel to conclude there may be valid reasons for NASA to have a role in the areas of Technology Demonstration and Technology Validation, depending on the circumstances of each individual situation--e.g., in cases where the promise of societal benefits is great and technical risks are high.

The panel's recommendations for NASA's role are summarized in the matrix shown in Figure 4. Specifically, the panel recommends that, without qualification, NASA play a major part in the first four roles (National Facilities and Expertise, Research, and both Generic and Vehicle Class Technology Evolution) with appropriate emphasis in all disciplines. In addition, if it is determined to be in the national interest, NASA play a part in the remaining four roles under the conditions noted in Figure 4, with each project considered on a case-by-case basis.

NASA ROLE CODE
1 Major Role
*2 Moderate Role
*3 Minor Role
*– No Role

ROLES	AERODYNAMICS	STRUCTURES & MATERIALS	PROPULSION	ELECTRONICS & AVIONICS	VEHICLE OPERATIONS	HUMAN ENGINEERING
NATIONAL FACILITIES & EXPERTISE	1	1	1	1	2	1
RESEARCH	1	1	1	1	2	1
GENERIC TECHNOLOGY EVOLUTION	1	1	1	1	2	1
VEHICLE CLASS TECHNOLOGY EVOLUTION	1	1	1	1	2	1
TECHNOLOGY DEMONSTRATION	$1^{a,b}$	$1^{a,b}$	$1^{a,b}$	$1^{a,b}$	$2^{a,b}$	$1^{a,b}$
TECHNOLOGY VALIDATION	1^{a}	1^{a}	1^{a}	1^{a}	2^{a}	1^{a}
PROTOTYPE DEVELOPMENT	$3^{a,c}$	$3^{a,c}$	$3^{a,c}$	$3^{a,c}$	$3^{a,c}$	$3^{a,c}$
OPERATIONS FEASIBILITY	$2^{a,d}$	$2^{a,d}$	$2^{a,d}$	$2^{a,d}$	$2^{a,d}$	$2^{a,d}$

NOTES:
(a) When national interest dictates
(b) Where components must be combined to evaluate the whole or where experimental flight testing is required
(c) With Congressional approval
(d) High risk - only way to evaluate

*If a proposed project or program initially falls in a recommended moderate, minor, or no-role category, but, following review of its merits on an individual case basis, is deemed to be a desirable undertaking by virtue of its being in the national interest, or mandated by the Congress or as a result of review it is concluded there are other overriding circumstances, then NASA's role for that project or program would be elevated to a major one (i.e., Category 1).

FIGURE 4 AIR TRANSPORT Role/Discipline Matrix

NASA'S ROLE IN GENERAL AVIATION AERONAUTICS

General aviation, including business aircraft and commuter airlines, is a rapidly expanding segment of the air transportation industry. The U.S. general aviation industry makes a significant contribution to the nation's transportation system, economy, and employment, the foreign trade balance, and U.S. prestige abroad. Over 90 percent of the international fleet of general aviation aircraft has been built in the United States. Currently, exports account for about 30 percent of U.S. general aviation production.

U.S. prominence in general aviation, however, is being eroded by foreign manufacturers in a number of areas. The majority of orders for heavy business jets and commuter aircraft is now held by foreign manufacturers, and their market share is increasing dramatically.

An improved flow of technology from NASA to the nation's general aviation industry is essential if the United States is to maintain a strong world position in the field. The Panel on General Aviation considers it unlikely that the general aviation industry can generate the required technology by itself. NASA is most suited to carry out the necessary research and technology development for general aviation. It has the facilities, the proven expertise, and the endorsement of industry to execute this work.

The panel decided that the current NASA research and technology effort is inadequate to provide the new technologies for general aviation on a timely basis, and would like to see NASA develop and implement a research plan in support of general aviation requirements consistent with industry goals.

As delineated in Figure 5, the panel recommends that NASA establish the leading role in basic research and technology development for general aviation. It strongly supported NASA roles in maintenance of National Facilities and Expertise, in Research, in Generic Technology Evolution, in Vehicle Class Technology Evolution, and in Technology Demonstration.

The panel recommends a moderate role for NASA in Technology Validation but no role in Prototype Development and Operations Feasibility. The panel recommends NASA involvement in all disciplines, except for a minor role, if any, for NASA in the area of avionics.

Specifically, the panel recommends that:

- NASA aggressively pursue a technology program that focuses on improving fuel efficiency and aircraft safety to assure U.S. supremacy in general aviation.

- NASA implement the role of leading the basic research and technology development effort in general aviation up through Technology Demonstration.

- NASA prepare a plan of research and technology development, in association with the general aviation industry, for urgent implementation.

NASA ROLE CODE:
1. Major Role
*2. Moderate Role
*3. Minor Role
*– No Role

ROLES \ DISCIPLINES	AERODYNAMICS	STRUCTURES & MATERIALS	TURBINE ENGINES	INT. COMBUST. ENGINES	PROPELLERS	PROPULSION: ELECTRONICS & AVIONICS	VEHICLE OPERATIONS	HUMAN ENGINEERING
NATIONAL FACILITIES & EXPERTISE	1	1	1	1	1	3	1	1
RESEARCH	1	1	1	1	1	–	1	1
GENERIC TECHNOLOGY EVOLUTION	1	1	1	1	1	3	1	–
VEHICLE CLASS TECHNOLOGY EVOLUTION	2	1	1	1	1	3	1	1
TECHNOLOGY DEMONSTRATION	1	1	1	1	1	3	1	–
TECHNOLOGY VALIDATION	–	2	2	2	2	–	1	–
PROTOTYPE DEVELOPMENT	–	–	–	–	–	–	–	–
OPERATIONS FEASIBILITY	–	–	–	–	–	–	–	–

*If a proposed project or program initially falls in a recommended moderate, minor, or no-role category, but, following review of its merits on an individual case basis, is deemed to be a desirable undertaking by virtue of its being in the national interest, or mandated by the Congress or as a result of review it is concluded there are other overriding circumstances, then NASA's role for that project or program would be elevated to a major one (i.e., Category 1).

FIGURE 5 GENERAL AVIATION Role/Discipline Matrix

NASA'S ROLE IN ROTORCRAFT AERONAUTICS

The Panel on Rotorcraft considers that research and the acquisition, continued upgrading, and operation of unique facilities are primary roles of NASA. These basic aspects of the NASA effort must not be compromised by the expansion of NASA's role in other areas.

The NASA role in Research is recommended by the panel to encompass all disciplines with the exception of that portion of avionics not related to flight control. Basic research in avionics is being addressed by the communications industry. However, there are basic research areas in which NASA has much to offer. Examples are digital computer software architecture and validation techniques for flight control systems.

Rotorcraft have unique requirements for research facilities. Under the terms of the Army/NASA cooperative agreement, NASA provides rotorcraft research facilities for use by the Army and NASA. NASA did an excellent job of building up such facilities during the 1970s, although some specific additions still are required (for noise and rotor icing research in particular).

The panel recommends a NASA role in Generic Technology Evolution pertaining to all disciplines except those in the communications and navigation areas of avionics. The Federal Aviation Administration should have prime responsibility in communications and navigation. Even so, NASA may have a unique contribution to make in a specific field such as the extension of global positioning system technology to

precision navigation and flight control of rotorcraft.

Technology Demonstration also is a recommended role for NASA in the rotorcraft sector. The complex synergistic interaction of all disciplines involved in rotorcraft, the relative immaturity of rotorcraft technology, and the resultant paucity of technical data make it essential that demonstration continue to be a key role for NASA in rotorcraft. Frequently, flight tests are the only way to verify research results and to demonstrate the applicability of new technology.

Technology Validation (risk reduction) can be particularly critical for rotorcraft because of the complexity, component interaction, and difficulty in predicting the effects of size. As civil rotorcraft continue to develop, their performance and operational requirements will diverge increasingly from those of the military, making it less feasible to use military prototypes to reduce risk in the use of new technology for civil rotorcraft. Some means of reducing the risk of incorporating and certifying new technology will be required if U.S. industry is to compete successfully in the worldwide civil rotorcraft market. A valuable role for NASA in validation, for example, would be to provide the data base to the FAA for the certification of new technology for the first user. This would ease the task of certification for later users. However, implementation of this role should not be allowed to have a significant adverse impact on NASA's basic research responsibilities. In view of this, the panel recommends a NASA role in Technology Validation only when:

- the work can be accomplished without reducing its role in fundamental and applied research,
- it is determined that NASA is the best agency for the task, and
- there is wide consensus as to the value and broad application of the results.

Prototype Development for rotorcraft is not a recommended role for NASA. Industry must assume the risks of prototype development for the civilian rotorcraft market, and the Department of Defense should continue its normal practice of sponsoring prototype development of military equipment.

Operations Feasibility is considered by the panel as a subset of Technology Demonstration. Whether or not it is a role for NASA depends upon whether the interaction of the rotorcraft with the environment in which it operates introduces significant uncertainty concerning the practicality or readiness of new technology.

It is recommended that NASA undertake Operations Feasibility when it is a key issue for the acceptance of a new concept and then only in close cooperation with and in support of the user. This is likely to be the case with unusual or unique aircraft systems or aircraft configurations when their efficient integration into an operational situation can be a critical factor. The panel also envisioned a supportive role for NASA in an operations feasibility demonstration of composite materials, or technology in which human factors are critical.

Recommendations concerning the roles for NASA in rotorcraft aeronautics are summarized by discipline in Figure 6.

NASA'S ROLES IN ENGINEERING EDUCATION

NASA operates some of the best research facilities in the world. These could be used in cooperation with universities to help allay a prospective shortage of engineers with advanced degrees. There is presently a shortage of engineers at the doctoral level as a result of a steady decline in the number of engineering doctoral degrees awarded by U.S. universities during the 1970s. Furthermore, about half of today's doctoral candidates in aerospace engineering are foreign nationals. This portends a future shortage of research workers for the nation's aeronautical and related industries and for NASA research centers. Moreover, an ensuing competition for graduates with advanced degrees may adversely affect the composition of engineering school faculties and thereby exacerbate the problem. The current shortage of faculty members with doctorates in U.S. engineering schools can only worsen unless corrected by making graduate engineering education more attractive to the best American undergraduates. In the 1960s, NASA instituted an academic fellowship program that was successful in helping in this regard. NASA is encouraged to explore this approach again, as well as others that might contribute to the solution of the problem of decreasing numbers of talented U.S. graduate students in science and engineering related to aeronautics.

NASA ROLE CODE:
1. Major Role
*2. Moderate Role
*3. Minor Role
*– No Role

ROLES \ DISCIPLINES	AERODYNAMICS	STRUCTURES & MATERIALS	PROPULSION	ELECTRONICS & AVIONICS	VEHICLE OPERATIONS	HUMAN ENGINEERING	FLIGHT CONTROL	AIRCRAFT SYSTEMS
NATIONAL FACILITIES & EXPERTISE	1	1	1	1	1	1	1	1
RESEARCH	1	1	1	1	1	1	1	1
GENERIC TECHNOLOGY EVOLUTION	1	1	1	1	1	1	1	1
VEHICLE CLASS TECHNOLOGY EVOLUTION	1	1	1	2	1	1	1	1
TECHNOLOGY DEMONSTRATION	1	1	1	2	2	1	1	1
TECHNOLOGY VALIDATION	3	2	3	3	3	3	2	2
PROTOTYPE DEVELOPMENT	–	–	–	3	3	–	3	–
OPERATIONS FEASIBILITY	3	2	3	3	3	2	3	1

*If a proposed project or program initially falls in a recommended moderate, minor, or no-role category, but, following review of its merits on an individual case basis, is deemed to be a desirable undertaking by virtue of its being in the national interest, or mandated by the Congress or as a result of review it is concluded there are other overriding circumstances, then NASA's role for that project or program would be elevated to a major one (i.e., Category 1).

FIGURE 6 ROTORCRAFT Role/Discipline Matrix

The workshop participants recommend that NASA explore means of contributing to the solution of the problem of decreasing numbers of talented U.S. graduate students in science and engineering related to aeronautics.

NASA'S ROLE IN INFORMATION DISSEMINATION

NASA's preeminence in aeronautical science and technology is recognized worldwide. Not only do many nations frequently use NASA data, but more recently they have been structuring government agencies in their countries to emulate NASA's operations. NASA's technological information flows freely to other nations. Other nations are more restrictive with their technological information. The workshop participants, recognizing the problem of worldwide technological competition in aeronautics, held varied opinions about the outward flow of research information. Some concluded that the United States should delay the flow of technological information considered critical to maintaining aeronautical leadership; others held that instead of delaying the dissemination, greater emphasis should be placed on continuing, and expanding if necessary, the effort to stay substantially ahead of other nations in aeronautical research and development. All agreed that NASA should ensure that the results of research and new technology developments should be disseminated to U.S. industry as early as possible. The distribution of such data to U.S. users at an early date prior to dissemination to foreign users is an option that is appropriate for many situations. Also, it was concluded that a focal point is needed to receive and assemble information about foreign technological advances and disseminate it to the U.S. aeronautical community. Therefore, it is recommended that NASA ensure that the results of research and new technology developments are disseminated to prospective U.S. users prior to the dissemination of such information to foreign users and that NASA become a focal point to receive information about foreign technological advances, assemble it into a usable form, and disseminate it to the U.S. aeronautical community.

NASA performs an important and irreplaceable function as a result of its research roles. Research results are of great and common value to the several sectors of the aeronautical community, and, by bringing together technological data from all of these sectors and by communicating this information to appropriate users, NASA increases the effectiveness of the total U.S. aeronautical research and development effort. Therefore, it is recommended that NASA continue to serve in the role of conducting aeronautical research that is broadly applicable, coordinating data from various sectors of the aeronautical community, and serving as a focal point for the dissemination of related information.

NASA's research and technology development efforts should be devoted to issues related to aeronautics and space. Broadening NASA's research capabilities to include work on technological problems in nonaerospace areas can seriously weaken NASA's ability to maintain a high level of effort in aeronautics. The workshop recommends that, in appropriate situations, NASA undertake a role in providing technical

information that can be applied to solving aeronautical problems facing other government agencies, but that NASA not extend further its role in research and technology development into fields other than aeronautics and space.

NASA'S ROLE WITH OTHER ORGANIZATIONS

Clearly, NASA is not the only contributor in the areas of aeronautical science and engineering. NASA works in partnership with the Department of Defense, the Department of Transportation, the Federal Aviation Administration, the universities, and the aircraft and airline industries. The NASA relationship with the aviation industry is particularly important in light of the current discussions about the needs and methods for strengthening relationships between the U.S. Government and all industries as a means of encouraging innovation, improving productivity, and retaining or increasing employment levels.

The complexities of adapting new science and technology in aeronautics to the solution of problems of society increasingly have involved more government agencies in aeronautical technology matters. For example, the Department of Agriculture and the U.S. Forest Service are interested in improvements in safety and efficiency of aircraft used for the aerial applications of pesticides and fertilizer. The Department of Energy is making use of NASA's extensive experience in thermodynamics, energy transfer, and fluid dynamics in the search for alternate sources of energy. NASA has done work in synthetic fuels that relates to the present responsibilities of DoE, and the results of NASA's work to improve aircraft energy efficiency are applicable to DoE conservation efforts. Similarly, there are long-standing interrelationships between NASA and the present National Oceanic and Atmospheric Administration in the collection and dissemination of weather data, as well as in research on techniques for increased automation of weather data collection, dissemination, and display. Such NASA research is also of interest to the FAA.

The cooperative and synergistic working relationships forged by NASA have been central to the success of U.S. aeronautics and could well serve as an example for other fields.

CURRENT AND FUTURE PROBLEM AREAS

The decade of the 1980s is likely to be characterized by new aeronautical opportunities and by problems with shifting priorities among them. Typical of the latter are the four problem areas listed below. None of them are new, and each has become more significant than it has been in the past. These dominant problems were continuously in the minds of the workshop participants. Each problem is subject to treatment within the roles for NASA that are recommended by the workshop. Government action is essential to their solution and is urgently recommended.

The four specific problems are:

- Increasing costs and decreasing supplies of petroleum demand

strenuous efforts toward the development of maximum efficiency in the use of aircraft fuel;

- o Engine noise and emissions control remain critical elements in aeronautical design and operations, as dictated by national concerns for improving the quality of life;

- o Air traffic congestion, particularly in the vicinity of airports, in metropolitan areas, is a serious concern, with potentially profound effects for the aeronautical community; and,

- o Uncertainties regarding the adequate supply of critical materials for aeronautical alloys dictate the development of effective substitutes.

While the workshop participants recognized that NASA is aware of and has done significant work in these areas, the critical nature of these problems is heightened by foreseeable forces in the 1980s. In view of this, it is recommended that NASA increase its attention to these critical problem areas and periodically assess its roles to ensure that its efforts in these areas are effectively meeting the needs.

III. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The workshop concluded that if the United States is to continue to reap the economic benefits of a strong civil aeronautical program and to have the security of a strong national defense, it must reaffirm its historical commitment to preeminence in aeronautical technology.

The conclusions and recommendations that follow were developed by the workshop participants as a whole. Other conclusions and recommendations specific to the various aeronautical community sectors, as represented by the panels, are contained in the separate panel reports and are summarized in Section II.

The following conclusions and recommendations are numbered for ease of reference and are not listed in any order of priority:

1. Conclusion: The U. S. has a multi-billion dollar investment in some special, high-technology facilities and equipment at NASA research centers. NASA has assembled first-class research and technical talent at these facilities. Both the NASA facilities and the assembled expertise represent a national resource that cannot be duplicated by industry. Accordingly, NASA needs to continue to carry out its responsibilities in research and technology development that flow from its great endowment of facilities and expertise.
   Recommendation: NASA expand and upgrade its facilities and technical personnel so that the United States can keep pace with the changes and opportunities afforded by the current status of aeronautical research and technology development.

2. Conclusion: NASA's most important contributions to all fields of aeronautics have been and will continue to be in the areas of research and technology development.
   Recommendation: NASA strengthen its efforts in the roles of Research, Generic Technology Evolution, and Vehicle Class Technology Evolution.

3. Conclusion: The central disciplinary areas pioneered by NASA--i.e., aerodynamics, materials and structures, and propulsion--are certain to be important areas of research for the future.

Each is of long-term importance to U.S. aeronautics. Although progress in these fields continues, there is a general deterioriation in U.S. capabilities relative to active foreign competition. NASA has a continuing responsibility that flows from its facilities endowment and great expertise for conducting programs in these areas.
Recommendation: NASA strengthen its roles in the disciplinary areas of aerodynamics, materials and structures, and propulsion to ensure U.S. leadership in these areas.

4. Conclusion: Substantial technological opportunities exist that are critically important to the future advancement of U.S. aeronautics. Assembling the body of research knowledge that enables advanced technologies to be applied to products is frequently a long-term effort. In notable cases, NASA has fulfilled this vital function.
Recommendation: NASA identify the most important areas of technological advancement and, when development time is likely to be long, assume the role of assembling a sufficient body of technical knowledge to enable U.S. industry to make effective and timely use of the new technologies. The development of composite primary structures and technology for the full use of active controls are two specific examples. Successful development and utilization of these technologies could provide the basis for world leadership in aeronautics by any major industrial nation.

5. Conclusion: Some research results and new technology require full-scale tests or experimental flight tests to obtain the data to evaluate a concept or to reach a final conclusion. It is important that NASA play a role in demonstrating the feasibility and validating the technical readiness of new components and system concepts. Such work is a necessary extension of the role in the evolution of technology when significant technical questions remain regarding the feasibility of a concept, or because of uncertainties regarding scale effects or interactions among components. The work should be undertaken by NASA when the potential benefits of using the technology are judged to be high. Examples of such programs include new technology to reduce fuel consumption, engine noise, and noxious exhaust emissions.
Recommendation: NASA undertake a role in Technology Demonstration and Technology Validation projects when the potential benefit to the country is judged to be high, after review and careful consideration of each individual case.

6. Conclusion: The acquisition and testing of experimental aircraft to explore the frontiers of flight in promising though unproven areas is a proper role for NASA. In the past, NASA's experimental aircraft programs have been important to the nation's development of new aircraft. In recent years, experimental aircraft programs have diminished in number.

Recommendation: NASA renew its leadership role in the acquisition and testing of experimental aircraft.

7. Conclusion: Safety is a field of overriding importance to aeronautics. Many of the technologies in which NASA has substantial capability are related to safety.
Recommendation: NASA examine all its roles and technical capabilities with the view to maximizing its contributions to the improvement of safety in aeronautics.

8. Conclusion: Human factors will play an increasingly important role in the areas of aviation safety and operational effectiveness. NASA has capabilities in the area of human factors research that have contributed to U. S. aeronautics. However, NASA's contributions in human factors research have been stronger in the large transport aircraft sector than in other sectors of the aeronautical community.
Recommendation: NASA develop its technological competence in human factors and expand its efforts, particularly as they relate to flight safety, and apply its capabilities to the general aviation and rotorcraft sectors.

9. Conclusion: Electronics will play an increasingly important role in the development of aeronautics in the future. In some areas of electronics, such as control systems for flight and propulsion, NASA has had an important role; in others, such as communications and navigation, NASA's role has been minor.
Recommendation: NASA continue to be selective in structuring its role in electronics. NASA should strengthen its role in areas of electronics that could benefit from its special expertise and experience as well as in those areas of electronics that are not being addressed adequately by other sectors of the aeronautics community.

10. Conclusion: At present, an insufficient number of talented students is pursuing graduate degrees in engineering and science to meet the needs of industry, university faculty, and the government.
Recommendation: NASA explore means of contributing to the solution of the problem of decreasing numbers of talented U.S. graduate students in science and engineering related to aeronautics.

11. Conclusion: Although NASA has clearly indicated that it bases its research and technology development programs on the needs of the different sectors of aeronautics, an appropriate balance among the several sectors has not been achieved. Historically, the military sector and the large transport aircraft sector have received far more NASA attention than have the general aviation and rotorcraft sectors of the aeronautical community.

Recommendation: NASA make a special effort to achieve appropriate balance in responding to the different and changing opportunities and needs of all sectors of the aeronautical community.

12. Conclusion: NASA performs an important and irreplaceable function by doing research that is of common value to the several sectors of the aeronautical community, by bringing together technological data bases from all of these sectors, and by communicating this information to appropriate users. This synergism serves to increase the effectiveness of U.S. aeronautical research and development efforts.
Recommendation: NASA continue to serve as a focal point for the development of technology data bases--i.e., conducting aeronautical research that is broadly applicable, coordinating data from the various sectors of the aeronautical community, and serving as a source and disseminator of related information.

13. Conclusion: The complexities of adapting new science and technology in aeronautics to the solution of various problems in U.S. society have increasingly involved more government agencies in aeronautical technology matters. For example, the Department of Energy is concerned with aviation fuel usage, and the Environmental Protection Agency is involved in aircraft noise and emission problems. NASA's technological capabilities in aeronautics are applicable to such matters. However, NASA's technological resources should be devoted solely to issues related to aeronautics and space. Diverting the focus of NASA to technological problems in non-aerospace areas will seriously weaken NASA's fine aeronautical and space efforts.
Recommendation: NASA establish a role in providing technical information that can be applied to the solution of problems of concern to other government agencies, but NASA should not extend its role in research and technology development into fields other than aeronautics and space.

14. Conclusion: NASA's preeminence in aeronautical science and technology is recognized worldwide. Not only do other nations frequently use NASA data, but more recently they have been structuring centers and institutes to emulate NASA's type of activities. NASA's technological information flows freely to other nations. Other nations, however, are more restrictive with their technological information. With respect to the worldwide technological competition in aeronautics, the workshop participants held varied opinions; some concluded that the United States should delay the flow of technological information considered critical to maintaining aeronautical leadership; others held that rather than delay the dissemination of research information, it is more effective to continue, and expand if necessary, the effort to stay ahead of other nations in aeronautical research and development.

Recommendation: NASA ensure that, in appropriate situations, the results of research and new technology developments are disseminated to U.S. users prior to dissemination to foreign users. In addition, NASA undertake to become a focal point to receive information about foreign technological advances, assemble it into a useable form, and disseminate it to the U.S. aeronautical community.

15. Conclusion: Clearly, NASA is not the only contributor in the areas of aeronautical science and engineering. NASA works in partnership with the Department of Defense, the Department of Transportation, the Federal Aviation Administration, the aircraft and airline industries, and the universities. The cooperative and synergistic working relationships that NASA has forged have been central to the success of U. S. aeronautics.
Recommendation: NASA continue its role and relationship in aeronautics with industry, universities and other government agencies as an exemplary procedure for effectively interacting with the private sector.

IV. DEFINITIONS OF ROLES AND DISCIPLINES

To facilitate the task undertaken by the participants in the ASEB workshop, a series of definitions of possible roles for NASA was developed. The roles represent steps in the hierarchy of the research and development process, beginning with a desire for knowledge and an understanding of basic phenomena, an idea, or technical concept, and ending with the design and construction of a vehicle, a vehicle component, or a new operational system.

Definitions of Possible Roles for NASA

Each of the following eight roles as defined by NASA was reviewed by the participants, and the panels considered the extent to which NASA should carry out these roles.

National Facilities and Expertise

This category comprises the development and maintenance of test facilities, including wind tunnels, simulators, and computers, as well as the maintenance of personnel with specialized skills, technical knowledge, and expertise in the field of aeronautics.

Research

Programs in this category are designed to gain basic knowledge and understanding of physical phenomena and processes in all discipline areas relevant to aeronautics. The work is fundamental in character and is performed within NASA, at universities, in industry, and by independent research organizations.

Generic Technology Evolution

This category involves the pursuit of the results of specific lines of basic research that show promise of generating technology broadly applicable to a number of classes of vehicles. The work is evolutionary in nature and leads to the continued advancement of technology.

Such advances generally precede focused technology development in support of specific vehicle class needs. The work is conducted primarily within NASA, with appropriate university and industry support.

Vehicle Class Technology Evolution

NASA programs in this category concentrate on specific vehicle classes and on the preparation of the unique technology data base required to improve the design and development of certain classes of aircraft. Activities include generating and evaluating new concepts and configuration approaches for the vehicle classes. Examples include V/STOL and supersonic cruise vehicles. In both cases, the technologies unique to those classes of aircraft are examined with regard to design feasibility, benefits, costs, etc. Then tailored data bases are developed.

Technology Demonstration

This category includes programs that are conducted to demonstrate the technical feasibility of a technology advance or concept. Activities may include flight testing and component or systems demonstrations. Specific examples in the current NASA program are: Tilt-Rotor Research Aircraft, Energy Efficient Engine, Quiet Short-Haul Research Aircraft, and Terminal Configured Vehicle. Future modifications and tests on an aircraft to demonstrate the feasibility of Laminar Flow Control and flight tests of an Advanced Turboprop would be included in Technology Demonstration.

Technology Validation

This comprises programs that include large-scale ground or flight validation as a necessary step to assure technology transfer. The purpose is to make possible, with minimal risk and without additional technology development, the practical utilization of high-benefit, high-risk conceptual, component, or subsystem technology advances. Specific examples in the present NASA program are: Composite Primary Aircraft Structure (CPAS), Materials for Advanced Turbine Engine (MATE), and Engine Component Improvement (ECI).

Prototype Development

This category consists of design, development, construction, and testing of an aircraft, engine, or system that is sufficiently representative of a planned final product to serve as a production prototype. An example of such a program for the civil sector would be the supersonic transport (SST) program conducted by the FAA during the 1960s. Current NASA programs do not include any prototype developments, and none is currently planned.

Operations Feasibility

This refers to operations conducted as research directed toward evaluating the feasibility or practicality of aircraft system operations to meet special needs or requirements or to demonstrate that a total, integrated operational system (e.g., new aircraft or simulated new aircraft, advanced integrated flight systems, approach and landing techniques, wake vortex alleviation, etc.) provides a service or benefit. The economic, environmental, and/or social aspects are considered.

Definitions of Disciplines

To assist in understanding the material summarized in Sections II and III, brief definitions of the discipline areas are provided.

Aerodynamics

Aerodynamics is the science dealing with the motion of air and other gases and with the effects of such motion on objects moving through such media.

Structures and Materials

This is the portion of aeronautical research and technology development dealing with the design of structures (the part of the aircraft, missiles and/or their components whose function is to carry loads in the broadest sense) and the materials used in aircraft and missile construction.

Propulsion

This disciplinary heading includes the part of aeronautical research and technology development relating to the various methods and systems for generating and delivering power for propelling and/or lifting aircraft and missiles.

Electronics and Avionics

Electronics refers to that aircraft and missile electrical equipment that is required for the basic operation of the vehicles--e.g., flight and engine controls. Avionics means the electrical equipment used for mission functions, such as air-to-ground communications and navigation. In military aircraft and missiles, the latter category includes offensive and defensive equipment and weapons control systems.

Vehicle Operations

This area deals directly with operational problems encountered by aircraft and missiles, such as icing, detection and dissemination of weather information, and air traffic control systems.

Human Engineering

This discipline addresses the study of human capabilities and problems that occur at the interfaces between the crew and the aircraft. It includes work on and use of simulators, crew workload studies, and studies of the optimization of cockpit instrumentation and controls.

ACKNOWLEDGEMENTS

The Aeronautics and Space Engineering Board thanks the workshop participants and the individuals who contributed many hours of work to conduct the workshop and to produce this report.

The information, assistance, support, and cooperation that the workshop panels received from NASA headquarters personnel and the personnel from NASA's aeronautics-oriented research centers (Langley, Ames, Lewis, and Dryden) were important to the entire effort. NASA Administrator Robert A. Frosch and Deputy Administrator Alan M. Lovelace participated in the plenary sessions, July 28 and August 1. The Acting Associate Administrator for Aeronautics and Space Technology, Walter B. Olstad, and the Acting Deputy Associate Administrator, C. Robert Nysmith were present throughout the workshop. The Research Center Directors--Donald P. Hearth of Langley, Clarence A. Syvertson of Ames, John F. McCarthy of Lewis, and Isaac T. Gillam of Dryden--were helpful in supplementing Mr. Olstad's presentation on July 29 about NASA's present activities and their evolution. The center directors also participated in the work of the panels with NASA headquarters personnel William Aiken, George Deutsch, Harry Johnson, John Ward, and Roger Winblade.

While the NASA personnel did not obtrude in the panel discussions, their attendance was not passive. They were always available to contribute their knowledge and insights about NASA activities, aims, programs, and accomplishments.

The ASEB is grateful to the following speakers for being so willing and generous in making their time and expertise available. Their contributions were immeasurably important and immensely appreciated. The speakers and their topics are listed in the order of presentation:

Robert A. Frosch Administrator National Aeronautics and Space Administration	Background and Questions on NASA's Role in Aeronautics

Alan M. Lovelace Deputy Administrator National Aeronautics and Space Administration	NASA's Roles and Concerns
Thomas R. Harkin Chairman, Subcommittee on Transportation, Aviation and Communication U.S. House of Representatives	The Legislative Outlook
Frederick W. Bradley, Jr. Senior Vice President Citibank, New York	The World Economic and Financial Outlook
John P. Longwell Professor, Department of Chemical Engineering Massachusetts Institute of Technology	The Outlook for Petroleum
Patrick J. Sheridan Manager, Manpower Activities American Association of Engineering Societies	Perspective on Engineering Manpower
Charles Law McCabe Vice President and General Manager High Technology Materials Division Cabot Corporation	The Outlook for Metallic Materials
Bill Wilkins Associate Administrator for Policy and International Aviation Affairs Federal Aviation Administration	The 1980s: A Decade of Revitalization for Aviation
William J. Perry Under Secretary of Defense Research & Engineering Department of Defense	The Outlook for Military Aeronautics
T.A. Wilson Chairman, The Boeing Company	The Outlook for Future Developments in Transport Aircraft
Malcolm S. Harned Senior Vice President Technology Cessna Aircraft Company	The Outlook for General Aviation
Gerald J. Tobias President, Sikorsky Aircraft Division United Technologies Corporation	The Helicopter's Future Fruition or Frustration?

Charles R. Foster Director, Northwest Region Federal Aviation Administration	How NASA Can Assist the FAA
Neal Blake Deputy Associate Administrator for Engineering and Development Federal Aviation Administration	How NASA Can Assist the FAA
Gershom R. Makepeace Director, Engineering Technology Office of the Under Secretary for Defense Research and Engineering Department of Defense	How NASA Can Assist the DoD
Walter B. Olstad Acting Associate Administrator for Aeronautics and Space Technology National Aeronautics and Space Administration	The Evolution of the Role of NACA and NASA Aeronautics and NASA's Aeronautics Capabilities

The effort of the participants was aided immeasurably by the excellence of the staff work provided before, during, and after the workshop. The effort of A.J. Evans as workshop project officer, was especially helpful in the planning and conduct of the workshop and in overseeing preparation of the report. Special thanks and recognition are due also to the other members of the ASEB staff, particularly Jean Fougstedt, Marlene Veach, and Laura D'Sa, and volunteers drawn from other units of the National Research Council, Barbara Candland, Delphine Glaze, and Frances Walton. Outstanding editorial assistance was provided by Linda Jenstrom in assembling the volumes of material produced by the panels and organizing it into a first draft of the report.

REFERENCES

1. Commission of the European Communities. Directorate General for Industry. The Aeronautical and Space Industries of the Community Compared with Those of the United Kingdom and the United States. (5 volumes)

   Vol. 1 The Aeronautical and Space Research and Development
   Vol. 2 The Aeronautical and Space Industry
   Vol. 3 The Space Activities
   Vol. 4 The Aeronautical Market
   Vol. 5 Technology--Balance of Payments: The Role of the Aerospace Industry in the Economy.

   Report No. 7042. Brussels, Belgium. Commission of the European Communities. July 1969.

2. A Policy for the Community for the Promotion of Industry and Technology in the Aeronautical Sector (56 pages plus 4 implementing texts and annexes I through V). Brussels, Belgium. Commission of the European Communities. July 19, 1972.

3. The Visions of MITI Policies in the 1980s. Report NR-226 (80-7). Tokyo, Japan. Ministry of International Trade and Industry. March 17, 1980.

4. "MITI Plans Development of New Aeronautical Technology." The Japan Economic Journal. June 10, 1980, p. 13.

APPENDIX A

THE EVOLUTION OF NACA/NASA IN AERONAUTICS

In 1915, the National Advisory Committee for Aeronautics (NACA) was established by Congress to "...supervise and direct the scientific study of the problems of flight with a view to their practical solution."

Accordingly, early emphasis was placed on scientific study, and the challenging new field of aeronautics attracted many gifted engineers and scientists to NACA. The Committee's laboratory at Langley Field became the national center of scientific aeronautical information, generating advanced work through theoretical studies, ground facility tests, and flight experiments. Studies and basic research there yielded much of the early theory in aerodynamics, propulsion, lightweight structures, and flight loads, which proved necessary for better understanding of "the problems of flight." Through the years, NACA, and later the National Aeronautics and Space Administration (NASA), expanded and enhanced its role in basic Research and Technology (R&T).

The NACA aeronautical laboratories at Ames and Lewis were established during the years preceding the entry of the United States into World War II. The Lewis Aircraft Engine Laboratory put the NACA squarely into the business of propulsion research and technology development which, prior to 1941, had been under the cognizance of the National Bureau of Standards. Both the Lewis laboratory and the Ames laboratory were placed close to centers of the aviation industry in recognition of the twofold purpose of serving the industry and learning from it.

During World War II, NACA, the military, and the industry worked as an effective, closely knit team. NACA concentrated on military technology needs. Virtually all new military airplanes were tested by NACA. Priority was given to developing solutions to specific problems such as stability and flight control, drag, high-lift systems, engine cooling, and engine performance. As a second priority, NACA continued to conduct a variety of research projects directed at possible future military needs. During this period, the synergism of day-to-day military problem-solving activities and in-house research proved extremely effective. Each clearly benefited from the other.

The war exposed problems related to the effects of air flow compressibility at high speeds. Subsequent research led to a better

understanding of compressible flows and means of avoiding or delaying the onset of compressibility phenomena. Foreign data acquired after the war, combined with the knowledge generated in the United States and the newly available jet engine, raised the hope of achieving practical supersonic flight. Because existing ground test capabilities were far from adequate, NACA undertook new, more sophisticated, and therefore more costly experimental programs. These included the high-speed research airplane program, the pilotless aircraft research program, and the construction of new transonic/supersonic wind tunnels.

To evaluate different designs for supersonic flight, a series of research airplanes--from the X-1 through the X-5, the D-558, and XP-92 --were developed, beginning in the mid-1940s. These permitted the investigation of straight, swept, and delta wing configurations. The speed with which such research aircraft were developed was due, in large part, to a continuation of the successful cooperative effort of NACA, the military, and industry established during the war years. NACA provided the technical support during development, conducted the research analysis, and reported the results; the Air Force and the Navy provided procurement, management, and funding; and industry constructed the airplanes. NACA and the military shared flight operations at the newly established NACA High Speed Flight Center (now the Dryden Flight Research Center). Although NACA became somewhat more involved in flight operations and flight research during this period, the programs involved no fundamental change in NACA's role.

The technology derived from these and other post-World War II ground and flight research programs was applied to the development of new military aircraft. In the mid-1950s, the industry began active exploitation of the new technology for civil transports. Later in this period, the X-15 was added to the research airplane series and several Vertical Take-Off and Landing (VTOL) and Short Take-Off and Landing (STOL) airplanes were developed under military contract and made available to NACA for research flight programs.

In a parallel development, Congress passed the Unitary Plan Wind Tunnel Act in 1949. This provided for a family of wind tunnels (subsonic to supersonic) at Ames, Langley, and Lewis. The tunnels were constructed for the primary purpose of "development support." They contributed a base for a complex of facilities that are not only unique in the nation but probably the best, in general, in the world. Later, the transonic aerodynamics facilities were developed at Langley. The facilities are not all that are unparalleled; the personnel who operate them and analyze the data also are unique simply by virtue of their intimate and extensive experience with the facilities and their knowledge about and access to the research data collected. While many of the facilities are used to perform tests on specific aircraft and missiles, they are extremely valuable for research.

NACA was assimilated into the National Aeronautics and Space Administration (NASA) under the National Aeronautics and Space Act of 1958. The Act states that the aeronautical activities of the United States government shall be conducted so as to contribute materially to one or more of the following objectives:

- o Expanding human knowledge of phenomena in the atmosphere;

- o Improving the usefulness, performance, speed, safety, and efficiency of aeronautical vehicles;

- o Preserving the role of the United States as a leader in aeronautical science and technology and the application thereof to conduct peaceful activities within and outside of the atmosphere; and

- o Making available, to agencies directly concerned with national defense, information about discoveries that have military value or significance, as well as providing appropriate civilian agencies with all information and discoveries that have value and significance to such agencies.

In the early 1960s, NASA undertook support of the proposed U.S. supersonic transport (SST) program. Research was conducted at the various centers; study contracts were let to the primary aircraft and engine manufacturers; and support was given to the Federal Aviation Administration in the evaluation of contractors' proposals.

In 1968, NASA conducted a series of in-house studies primarily oriented toward civil transports. The studies were intended to support the U.S. transport aircraft and engine manufacturing industries with the timely availability of new technology. The studies explored long-haul subsonic and supersonic transports and short-haul subsonic transports (VTOL and STOL). With the guidance of review panels made up of representatives of NASA, FAA, and industry, the course of the work gradually changed. Eventually, the original concept of developing research prototypes was eliminated in favor of emphasizing the development of advanced technologies and developing and testing their applications.

Experimental aircraft developed during this period included the Quiet Short-Haul Research Aircraft (QSRA), the Rotor Systems Research Aircraft (RSRA), the Tilt-Rotor Research Aircraft, and the Quiet Nacelles for Long-Haul Aircraft. Modifications of existing aircraft were made to flight test laminar flow control, wings with augmented lift, supercritical wings, and fly-by-wire control systems. Experimental engine programs were initiated, including the Refan and Quiet Engine Programs for reducing engine noise; the Quiet, Clean, Short-Haul Experimental Engine (QCSEE) Program; and the Quiet, Clean General Aviation Turbofan (CGAT) Program.

In such instances, the hardware was used to test concepts. No prototypes were developed. The experimental aircraft were intended to facilitate collecting technical data, as well as to accelerate transfering the data to industry for production applications. However, the experimental engine programs did extend NASA's traditional role in aeropropulsion technology from research efforts on engine components to support of the design and testing of complete engine systems.

During the mid-1960s, NASA also accelerated its research on the basic sources of jet engine noise and the reduction of noise levels and

engine emissions. This effort was an example of research into areas of public concern. Thus, NASA fulfills a unique role when research and technology development are required for the public good in areas where there is little or no potential profit to motivate the private sector.

The extension of NASA's role in aeronautics was again accelerated when the Aircraft Energy Efficiency Program (ACEE) was established in 1975. ACEE grew out of increasing national concern about the rising cost and decreasing availability of fuel after the Arab oil embargo of 1973-1974, and their implications for continued U.S. leadership in air transportation. The ACEE program was developed by NASA in response to a request from the Senate Committee on Aeronautical and Space Science for programs aimed at improving the energy efficiency of transport aircraft.

Through the ACEE program, NASA is funding technology advances leading directly to product improvements in propulsion in the Engine Component Improvement (ECI) program and in airframes in the Energy Efficient Transport (EET) program. Thus, NASA is also funding industry for work to improve existing airframes and engines in order to expedite fuel conservation until new airplanes or engines can be designed and built.

In the Energy Efficient Engine (E^3) program of ACEE, NASA is funding parallel efforts by the two major domestic engine manufacturers to design, develop, build, and test advanced engine components to establish a technology base for the next generation of turbofan aircraft engines. By providing support through the proof-of-concept phase to reduce technical risk, NASA encourages early commitment by engine manufacturers to the large investments required for engine development.

In the Composite Primary Aircraft Structures (CPAS) program, NASA has funded the large transport airframe contractors to design and test medium-to-large structural aircraft components manufactured from lightweight composite materials. This effort also includes field service evaluation and aid in meeting regulatory standards. The prime objective is to accelerate the needed research so that the industry can adopt composite materials in new aircraft.

NASA's role in 1980 has evolved from the "scientific study" emphasis of the 1915 NACA legislation to include:

- o National Facilities and Expertise;
- o Research;
- o General Technology Evolution;
- o Technology Demonstration; and
- o Technology Validation.

NASA is a different organization than NACA. It is not governed by a committee structure, although it does continue to rely greatly on its advisory committee. In the course of its development, NASA has been preoccupied with the space program, and this mission continues today.

Fortunately, like the old NACA, NASA is still an independent agency, and it still has no regulatory role.

NASA fulfills a unique and vital role in support of U.S. aeronautics, and, because NASA serves both military and civil aviation, the maximum utilization of scarce facilities and skilled manpower is ensured.

The partnership that now exists between NASA, the aeronautics industry, and the DoD has evolved over two-thirds of a century. It is a unique working relationship that is an exemplary procedure for effectively interacting with the private sector. It started when aviation was in its infancy and has evolved to its present state as the discipline expanded and matured. It would be difficult to create such a relationship between the government and a mature industry.

NASA Capabilities

NASA research capabilities depend on the size and quality of its research staff, the research facilities available to this staff, and the funds available to support research efforts.

Research Staff

Figure A-1 shows NACA/NASA aeronautics manpower during the past 60 years. The chart displays the peaking that occurred during and after

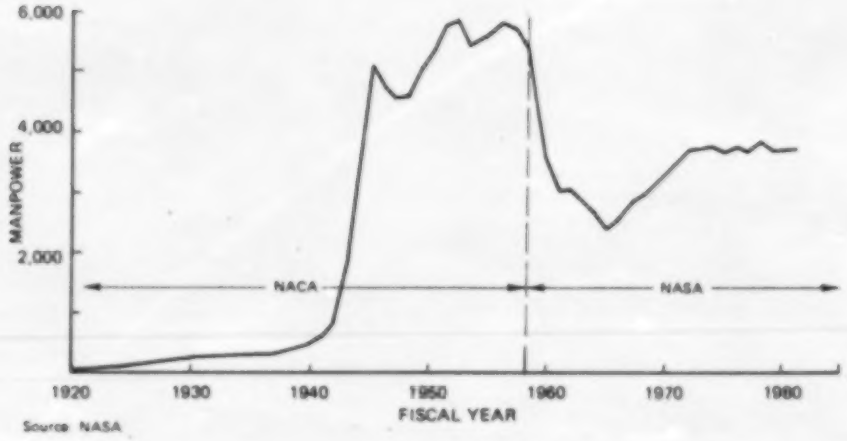


FIGURE A-1 NACA/NASA Aeronautics Manpower History

World War II. Following the creation of NASA in 1958, a sharp drop in aeronautics manpower occurred because of the agency's important new responsibilities for the space effort. A full-blown and well-funded

space program resulted in significant diversions of manpower and managerial attention and emphasis to this activity. Aeronautical research in the United States suffered in consequence. Moreover, the NACA subcommittee structure, which had been functioning effectively, was abolished, and a new organizational structure was created.

The decline which began in the late 1950s was followed by a build-up beginning in 1964, and today the manpower level is approximately 64 percent of the World War II peak. However, the portion of NASA's aeronautics manpower engaged in research has fallen by 44 percent. Recently, this staff has been aging at a rate of one-half year per year because of the low replacement rate of retirees.

Research is placed with universities and industry under contract, and this has helped mitigate a potentially disastrous situation. The increased use of such contract efforts has resulted in higher dollar expenditures without a corresponding increase in NASA manpower.

Facilities

There are four NASA research centers concerned primarily with aeronautical research. These are the original NASA center, the Langley Research Center in Hampton, Virginia, dedicated in 1920; the Ames Research Center in Northern California; Dryden in Southern California; and Lewis, the propulsion research center near Cleveland, Ohio.

Table 1 shows the distribution of personnel and funding among these centers, and Table 2 summarizes the functions performed at each.

The development and operation of experimental facilities always have been major tasks of NACA and NASA. Indeed, the NASA facilities

TABLE 1 NASA Aeronautics Program Resources

Center	FY 1981 Direct Civil Service Staff	FY 1981 Direct Scientific and Engineering	FY 1980 R & D* ($ M)
Ames	655	358	50.5
Dryden	301	123	12.5
Langley	1,482	705	120.2
Lewis	1,211	604	117.9
Other	123	66	7.2
Totals	3,772	1,856	308.3

*This R & D budget does not include salaries of personnel, travel, or certain operating expenses such as utilities and construction of facilities.

Source: NASA.

TABLE 2 Functional Roles of NASA's Research Centers

Ames Research Center	*Langley Research Center*
○ Short-Haul A/C Tech.	○ Long-Haul A/C Tech.
○ Helicopter Tech.	○ Acoustics and Noise Reduction
○ Fundamental Aerodynamics	○ Aerospace Vehicle Structures and Materials
○ Computational Fluid Dynamics	○ Avionics Technology
○ Flight Simulation	○ General Aviation A/C Tech.
○ Human-Vehicle Interactions	○ Fundamental Aerodynamics
○ Military Support	○ Military Support
Dryden Flight Research Center	□ Helicopter Tech.
○ Aeronautical Flight Research	□ Hypersonic Propulsion Systems
	□ Computational Fluid Dynamics
Lewis Research Center	
○ Air Breathing Propulsion Systems	

○ Primary Role
□ Supporting Role
Source: NASA.

are unparalleled. The current development of the National Transonic Facility (NTF) at Langley and the proposed Numerical Aerodynamic Simulator (NAS) at Ames are two examples of NASA's continuing efforts to remain in the lead in research facilities. But success breeds competition. The Europeans now are constructing a cryogenic tunnel for transonic testing that is designed to match the NTF's capabilities, and the Japanese plan to have Hitachi build a computer for their aircraft industry that will be comparable to the proposed NASA National Aerodynamic Simulator.

Historically, the NASA aeronautics laboratories have been late in acquiring state-of-the-art scientific computers. NASA laboratories currently are deficient relative to other government laboratories and will soon be deficient relative to the European aeronautical laboratories. Scientists in the Department of Energy and in universities studying the magnetic confinement of plasma have access to a computer complex at Livermore, California, that includes a Cray 1, a DCD 7600, and a DEC 10, as well as other, smaller computers. Comparable facilities do not exist at any U.S. aeronautics center. If NASA were to move today to purchase the most advanced computers now available, the staff would find themselves in line behind their European counterparts.

Funds

Figure A-2 shows the funding history of NASA aeronautics from 1930 to 1980 in constant FY 1980 dollars (adjusted for inflation). A sharp peak in expenditures occurred during World War II. The large spike in the early 1950s represents the Unitary Plan Wind Tunnel Act. With the creation of NASA in 1958 the funding for aeronautics declined to about one half its value for fiscal years 1960 and 1961. Expenditures began to increase in the early 1960s and peaked in 1979 higher than the previous peak in 1950. However, funding appears to be declining again in fiscal years 1980 and 1981.

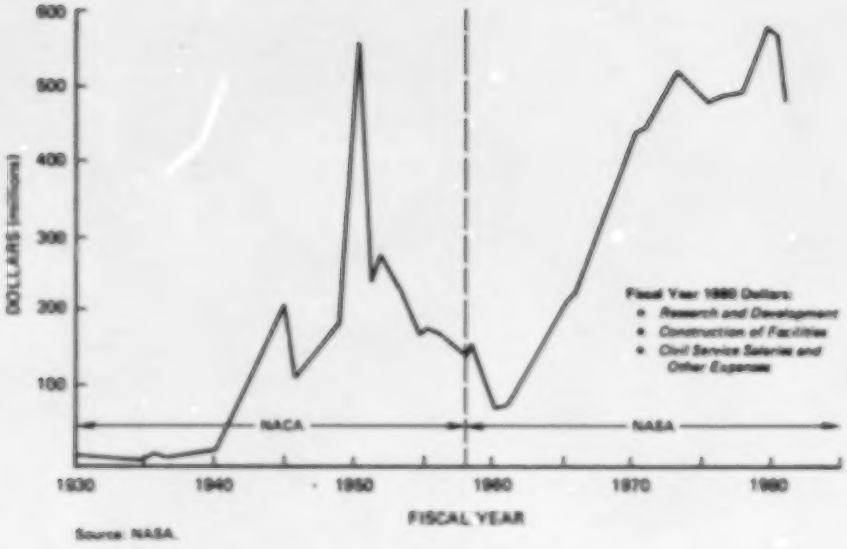


FIGURE A-2 NACA/NASA Aeronautics Funding History

APPENDIX B

NASA'S INSTITUTIONAL RELATIONSHIPS

Much of the success of U.S. aeronautics can be attributed to the nation's rapid advances in research and technology. Historically, these advances have been a product of cooperation between the government and both the military and civilian sectors of U.S. aviation. Military needs are identified for NASA through close cooperation and coordination with the Department of Defense and the technical staffs of the military services. Commercial and consumer needs are defined for NASA by the airlines, the aerospace industry, and government regulatory agencies such as the Federal Aviation Administration. Thus, technology needs are often identified for NASA by the users; similarly the translation of the technology capabilities developed by NASA to useful applications occurs through the other agencies or institutions.

NASA supports advanced aeronautical research, and the findings of such research often point the way to new developments in both civil and military aircraft. The technical capabilities developed by NASA at the system and sub-system levels have helped to secure the defense of the nation and enabled U.S. industry to compete successfully in the world market.

Interface Methods

NASA has established a number of successful methods of working with the large number of government laboratories, agencies, and industrial concerns that together make up the aeronautical assets of the United States. Similar arrangements also are used to coordinate a limited number of international programs.

The basic method used to implement joint or cooperative programs between NASA and other agencies is a Memorandum of Agreement (MOA) that generally describes the areas of mutual activity in fairly broad terms. The MOA becomes the umbrella under which a number of specific tasks or project agreements are written. Such agreements usually contain a detailed description of the work to be done, a chart of project milestones, and a description of funding requirements, including any agreements on joint funding.

Each agency entering into such an agreement establishes one or more coordination points. Characteristically, these are at the Associate Administrator level, as well as the agency service level, if appropriate. The programs are reviewed periodically at both levels so that needed changes or policy decisions can be made. In addition, program coordination points are established at the operational level, both within NASA and the respective agency, so that the day-to-day coordination of each program is expedited. Within these general guidelines, however, a great deal of latitude exists in the actual working relationships of each program. Descriptions of the variety of arrangements are given below.

- Establishment of an agency program office at a NASA facility: Such a program office also may have responsibility for operating a major NASA facility such as a wind tunnel. This type of program arrangement may have a mixture of agency, NASA, and contractor personnel working on a technology of common interest. Such a program may also involve university support, either through contracts or by virtue of direct, on-site support. However, the responsibility for the program resides with the agency.

- Establishment of an agency technical office at a NASA facility with responsibility for coordination and oversight on a number of agency programs: In this case, the office consists of technical and program people who participate in the technical work on the key coordinated programs conducted at the facility. The responsibility for the programs is shared with NASA.

- Establishment of joint programs: When agencies establish joint programs, they may be organized in either of the ways described above. In the past, NASA and one or more other agencies have undertaken a series of tasks leading to the development of a new technology that, in turn, had direct application to new aircraft or aviation-related systems.

- Establishment of coordinated programs: This type of arrangement is instituted when NASA and another agency want to explore several different technologies or approaches to the solution of a particular need or problem. It facilitates the orderly assessment of technology leading to the fulfillment of a particular need.

- Establishment of a joint agency agreement: Such an agreement can have various options. An example is the joint Army/NASA agreements on low-speed aeronautics. This agreement is broad enough to allow joint tasks at individual centers as well as expansion of specific NASA facilities. By virtue of this agreement, there is joint involvement of each agency in the formation of both the Army and the NASA rotorcraft programs.

NASA Interfaces with Other Government Agencies

NASA's relationships with other government agencies are characterized by a high degree of diversity, although the formal mechanisms previously described provide a consistent framework for conducting interagency programming. NASA has had close historical ties with DoD. In the civil sector, NASA's expertise and the responsibilities assigned to the FAA provide fertile ground for closely coordinated programs. NASA also serves other government agencies when its capabilities and the expertise of its personnel can contribute to the solution of problems.

NASA and the DoD

NASA and the military services have developed an array of effective working relationships, ranging from high-level coordination of decisions on the one hand to the daily technical interactions between working scientists and engineers on the other. An extensive number of joint or interdependent programs now exist (see examples listed in Table 6, Volume II). Formalized review activities, such as those conducted by the DoD/NASA Aeronautics and Astronautics Coordinating Board and the AFSC/NASA Interdependency Review Group provide the basis for management decisions and formalized Memoranda of Understanding (MOU). MOUs for joint activities are negotiated at the laboratory/center management level in cases in which the size of the program and policy issues are within their purview (with visibility provided to higher management).

Coordination and mutual understanding at the laboratory management and engineering level are enhanced by the interchange of personnel and the assignment of representatives to major laboratories or centers. The sharing of technical information, the conduct of experimental testing, and other joint activities are carried out directly between organizations at the working level and reported more formally to higher management.

The NASA rotorcraft program is an excellent example of the efficacy of such arrangements. NASA's continued support of the DoD in the development of rotorcraft technology is essential. Both the Army and Navy benefit from this relationship. The program is particularly important to the Army because it is the principal user of helicopters and it has no research facilities of its own.

The Army/NASA agreement and the subsequent cooperation are probably not excelled anywhere in the realm of government interagency cooperation in terms of mutual support, responsiveness, and efficiency. Cooperation in the use of resources, including personnel and facilities, has been highly effective. Continuation of the current levels of effort and consultation and cooperation in addressing solutions to specific problems are essential to the viability of the Army/NASA relationship.

The existing relationship, when assessed in terms of the return on the investment by both agencies, rates extremely high. NASA/Army cooperation has provided the nation with a valuable asset to meet new and future civil and military requirements.

NASA and the FAA

The FAA is responsible for the certification of aircraft, flight personnel, and airports, as well as the design, implementation, and operation of the nation's Air Traffic Control (ATC) system. The FAA also is responsible for promoting U.S. aviation, as evidenced by its SST research and development efforts. In discharging its mission, the FAA uses the expertise of other government laboratories, universities, and industry in providing the needed technology base and in developing the various system elements required.

The FAA looks to NASA for the basic research and technology development in areas in which the current technology base is not adequate, as well as for direct program support in certain critical cases. The output of NASA programs provides the data base needed to formulate advisory circulars and regulations and to develop new ATC system elements. The advisory circulars and regulations form the basis for the FAA certification process.

NASA and FAA have established a formal coordinating committee and supporting process to define and carry out cooperative programs in a number of major areas--e.g., aviation safety, aviation meteorology, aircraft noise, air pollution, aviation fuels, short haul transportation, airport/aircraft avionics systems, materials and structures, human factors, and other related fields, including general aviation technology, emergency locator transmitter systems, helicopter operations under instrument flight rules and pilot training.

New coordinated programs are established when FAA has a requirement for system improvement and NASA has the facilities and/or the expertise to provide the needed technology. The programs conducted in the general areas listed above are revised periodically as the activities are completed and the requirements change.

FAA also has established field offices at two of the NASA facilities to ensure a high degree of coordination in key program areas. NASA currently has capabilities that are not fully exploited in support of FAA research objectives. Clearly, areas of cooperation do exist, and their number is growing. Some of the most significant challenges in air transportation are within FAA's responsibility, and in a portion of these NASA can help. It is important to bring NASA's resources to bear on certain critical technical problems that are under the purview of FAA.

Other Agencies

NASA also provides technical support to or has working relationships with other government agencies. The Department of Agriculture and the U.S. Forest Service are interested in improvements in safety and efficiency in aircraft used for the aerial applications of pesticides, fertilizers, etc. The Department of Energy is making use of

NASA's extensive experience in thermodynamics, energy transfer, and solar energy, as well as its knowledge of wind and fluid dynamics and several aspects of its alternative energy program. NASA has done work in synthetic fuels that relates to the present responsibilities of DoE. In fact, NASA's whole aircraft energy efficiency program is of importance to the DoE conservation efforts.

There are long-standing interrelationships between NASA and the present National Oceanic and Atmospheric Administration in the collection and dissemination of weather data, as well as in research on the increased automation of weather collection, dissemination, and display. Such programs are of interest to the FAA as well.

NASA Interfaces with Universities

Historically, the relationship between NASA and universities has been a good example of how academic researchers can be involved early on problems of national security and economic concern, even while assuring their broad independence and freedom in academic sciences. The flow of ideas from universities into NASA and its research centers and from NASA to universities has been effective, mutually reinforcing, and beneficial.

NASA/university interfaces usually take one of the following forms:

- Maintenance of University Centers of Aeronautics Expertise: The approach of allocating aeronautical research funds to universities has proven successful and effective. Obviously, the funds required to maintain such centers of expertise and excellence are continuing and substantial. It is important to note that the participation of foreign students in these centers increased substantially during the past two decades. A review of how to maintain and increase U.S. student participation in these centers of expertise is required. Scholarships, awards, prizes, and other incentives may have to be reassessed.

- Independent Generic and Basic Research: Because of funding limitations, project-specific R&D has been emphasized by NASA through each of its research centers at the expense of generic basic research. The reestablishment of an independent line item, preferably at NASA Headquarters, for university non-project-specific (generic) aeronautical research would remedy this situation. Such generic research could deal with fundamental issues in aeronautics --e.g., theoretical limits to performance improvements, noise reduction, automation, and robotics.

- Personnel Interchange between NASA Research Centers and Universities: In the past, assignments to NASA laboratories and research facilities were an important part of academic achievement and advancement. The role of NASA in this area has diminished during the last decade. Specific steps should be taken to ensure personnel interchange between universities and NASA research centers, thus facilitating the active interchange of technical knowledge.

The importance of improving the relationship between NASA and U.S. universities should not be underestimated. Universities have a constant supply of bright, young talent, as well as easy access to and cross-fertilization with other fields of science and engineering. In such an environment, steady progress toward the understanding of a given technical field, such as turbulence, is more natural than is the rapid solution of a specific problem. The latter can be done more effectively by others.

During the 1970s, there was a steady decline in the number of engineering doctoral degrees awarded by U.S. universities.[1] In addition, at present about half of the doctoral candidates in aerospace engineering are foreign nationals.[2] This portends a future shortage of research personnel in U.S. aeronautical and related industries and at NASA research centers, with an ensuing competition for graduates with advanced degrees that may adversely affect the composition of engineering faculties and thus exacerbate the problem. There is presently a shortage of faculty members with doctorates in U.S. engineering schools. The situation is likely to worsen unless it is corrected by making graduate education in engineering more attractive to the best undergraduates. NASA was successful in doing this in the early 1960s.

NASA operates research centers with some of the best facilities in the world; at best, university laboratories are equipped with sophisticated instrumentation, but none has research and development facilities to equal NASA's. In many ways, this situation is similar to one existing in fields requiring the use of large particle accelerators. Here "user groups" are formed in universities; faculty members prepare experiments at their home base and subsequently use the accelerator at a national laboratory for a rigorously scheduled time. Similar arrangements should be possible in aerodynamics, in particular in facilities such as the National Transonic Facility.

The research modes of NASA and universities are complementary. However, differences in operation have to be kept in mind. NASA has better access to "real" problems, while the universities are a fertile field for novel ideas and techniques, stimulated by contacts with fields other than aeronautics. To a certain extent, cooperative efforts are underway already, but they can be strengthened significantly both through grants and contracts and through exchanges of personnel between the NASA centers and the universities.

In the 1960s NASA granted academic fellowships up to $6000 a year to attract talented students. Approximately 1,000 students were recipients of the NASA fellowships in any one year. It could be useful to fund such a program today.

NASA Relationships with Industry

There are two facets of NASA's relationships with industry. The first relates to the transmission of a clear perception of industry's research needs to NASA. This is accomplished primarily through the NASA Advisory Committee but also through system studies. The second facet is the transfer of technology from research conducted by NASA through technical symposia, workshops, NASA reports, research progress

reports, and contracts with industry.

NASA Relationships with Foreign Agencies: Technology Export

Technology transfer to U.S. competitors abroad is a cause of concern. It is recognized that it would not be desirable, even if it were possible, to restrict NASA's data dissemination in general. There are occasions, however, when it would be in the best interests of the United States to withhold research results and new technology from worldwide dissemination, particularly technological innovations and critical data. The dissemination of such information to U.S. users at an early date prior to dissemination to foreign users is an option that is appropriate for many situations. This is a matter requiring the attention of technical management personnel at the NASA research centers, and it must be handled with a good deal of judgment. Laxity in this regard could leave NASA open to the criticism that U.S. tax dollars are not being used in a manner that reaps the fullest benefits for U.S. interests and well-being. Of course, when advances pertain to technology directly applicable to military aircraft, military security classifications will apply.

References

1. National Academy of Engineering. Issues in Engineering Education; A Framework for Analysis. Task Force on Engineering Education. April, 1980.

2. Patrick J. Sheridan. Perspective in Engineering Manpower. Presentation at ASEB Workshop on The Role of NASA in Aeronautics, Woods Hole, Massachusetts. July 28, 1980.

APPENDIX C

BIBLIOGRAPHY

National Academy of Engineering, Aeronautics and Space Engineering Board. Civil Aviation R&D, An Assessment of Federal Government Involvement. Washington, National Academy of Engineering. 1968.

NACA--Model Agency for Government Research. Air Force Magazine. February, 1968. (pp. 50-57).

Office of Technology Assessment. Impact of Advanced Air Transport Technology, Part I--Advanced High Speed Aircraft. Washington, U.S. Government Printing Office. 1980.

Piper, Stephen W. The Agreement on Trade in Civil Aircraft. Testimony before the Subcommittee on Transportation, Aviation and Communication of the Committee on Science and Technology. Washington, U.S. House of Representatives. October, 1979.

Taylor, Quentin S. The Shape of the System of the Future. Washington, Federal Aviation Administration. 1980.

U.S. Department of Defense, National Aeronautics and Space Administration, and Department of Transportation. R&D Contributions to Aviation Progress (RADCAP), Volume 1, Summary Report. Washington, U.S. Department of Defense. August, 1972.

U.S. Department of Transportation and National Aeronautics and Space Administration. Civil Aviation R&D, Policy Study. Washington, U.S. Dept. of Transportation and National Aeronautics and Space Administration. March, 1971.

U.S. House of Representatives. Committee on Science and Technology. The Future of Aviation - A Compilation of Papers, Vols. I & II. Hearings before the Subcommittee on Aviation and Transportation Research and Development. 94th Cong., 2nd sess. Washington, U.S. Government Printing Office. 1976.

U.S. National Aeronautics and Space Administration. Outlook for Aeronautics. Washington, National Aeronautics and Space Administration. March, 1976.

U.S. Senate. Committee on Commerce, Science, and Transportation. Committee Print. National Aeronautics & Space Act of 1958, as Amended, and Related Legislation. 95th Cong., 2nd sess. Washington, U.S. Government Printing Office. December, 1978.

APPENDIX D

WORKSHOP PANELS' MEMBERSHIP

WORKSHOP ON
THE ROLE OF NASA IN AERONAUTICS
Aeronautics and Space Engineering Board
Robert W. Rummel, Chairman

H. Guyford Stever, Workshop Chairman
Chairman, Assembly of Engineering
National Research Council

WORKSHOP ON
THE ROLE OF NASA IN AERONAUTICS

MILITARY AVIATION PANEL

Frank A. Cleveland, Chairman
Vice President--Engineering
Lockheed Corporation

Harold Andrews
Director, Advanced Aircraft
Development and Systems
Objectives
Commander, Naval Air Systems
Command
Department of the Navy

Robert C. Barlow
Director, Flight Dynamics
Laboratory
Wright Patterson Air Force Base

Welko E. Gasich
Senior Vice President, Advanced
Projects
Northrop Corporation

Robert R. Gilruth
Retired Director
NASA's Manned Spacecraft
Center, Houston

Grant Hansen
President, The Systems Group
Systems Development Corporation

Jack L. Kerrebrock
R.C. Maclaurin Professor and
Head, Department of
Aeronautics and Astronautics
Massachusetts Institute of
Technology

William E. Lamar
Retired Deputy Director of
Technology Integration
Wright Patterson Air Force
Aeronautical Laboratory

Robert B. Ormsby, Jr.
President
Lockheed-Georgia Company

Joseph F. Shea
Sr.V.P.and Special Asst.
to the Executive Office
Raytheon Company

Raymond F. Siewert
Staff Specialist for
Aeronautics Engineering
Technology
Office of the Under Secretary
for Defense Research and
Engineering
Department of Defense

Edward Woll
Retired Vice President
Project and Technology
Assessment Group
General Electric Company

WORKSHOP ON
THE ROLE OF NASA IN AERONAUTICS

TRANSPORT AIRCRAFT PANEL

John E. Steiner, Chairman
Vice President, Corporate Product Development
The Boeing Company

Joseph B. Bidwell
Executive Director
General Motors Research Labs

Richard E. Black
Director, Technologies
Douglas Aircraft Company

John G. Borger
Vice President, Engineering
Pan American World Airways, Inc.

Robert N. Buck
Retired Chief Pilot
Trans World Airlines, Inc.

Richard J. Coar
Executive Vice President
Power Group
United Technologies Corporation

Charles R. Foster
Director, Northwest Region
Federal Aviation Administration

Russell H. Hopps
Vice President and General Manager, Engineering
Lockheed California Company

James W. Mar
Jerome C. Hunsaker Professor of Aerospace Education
Department of Aeronautics and Astronautics
Massachusetts Institute of Technology

Duane T. McRuer
President
Systems Technology, Inc.

Gordon Sim
Vice President, Program Management
Rohr Industries, Inc.

Robin H. H. Wilson
Senior Vice President
Operations
Trans World Airlines, Inc.

WORKSHOP ON
THE ROLE OF NASA IN AERONAUTICS

GENERAL AVIATION PANEL

Malcolm S. Harned, Chairman
Senior Vice President, Technology
Cessna Aircraft Company

M. Craig Beard
Director of Airworthiness
Federal Aviation Administration

George W. Church
Vice President and General Manager
Avionics Division
Bendix Corporation

David C. Hazen
Professor, Department of
Aeronautics Engineering
Princeton University

Charles E. Morris
Manager, Aircraft Operations
Department
Mobil Oil Company

John W. Olcott
Editor
Business and Commercial
Aviation Magazine

Harold W. Paxton
Vice President, Research
U.S. Steel Corporation

Chester Rembleske
Vice President, Engineering
Beech Aircraft Corporation

Ivan Speer
Group Vice President
Aircraft and Aerospace
The Garrett Corporation

Edward W. Stimpson
President
General Aviation
Manufacturing Association

Leslie Waters
Vice President, Aeronautical
Engineering
Aircraft Products Division
Teledyne Continental Motors

WORKSHOP ON
THE ROLE OF NASA IN AERONAUTICS

ROTORCRAFT PANEL

Edward S. Carter, Chairman
Director of Technology
Sikorsky Aircraft Division
United Technologies Corporation

Holt Ashley
Professor, Department of
Aeronautics and Astronautics
Stanford University

Richard L. Ballard
Chief, Technology Support Team
Aviation Systems Division
Department of the Army

B. Paul Blasingame
Retired Manager, Santa Barbara
Operations
Delco Electronics Division
General Motors Corporation

Arnold Brooks
Manager, Advanced Engineering
Program
General Electric Company

Glen A. Gilbert
Glen A. Gilbert Associates

Harlan S. Hosler
Chairman, Helicopter
Operation Task Forces
Office of Aviation Safety
Federal Aviation
Administration

John Kerr
Vice President, Engineering,
Research and Development
Division Summa Corporation
Hughes Helicopter

Stanley Martin
Director, Advanced Product
Design and Development
Bell Helicopter Textron

James R. Nelson
Chief, Helicopter Systems
Branch
Federal Aviation
Administration

William Walls
Director of Technology
Boeing Vertol
The Boeing Company

WORKSHOP ON
THE ROLE OF NASA IN AERONAUTICS

OVERVIEW PANEL

A Richard Seebass - Co-Chairman
Department of Aerospace and
Mechanical Engineering
University of Arizona

R. Dixon Speas - Co-Chairman
President
Aviation Consulting Incorporated

Neal Blake
Deputy Associate Administrator
for Engineering and Development
Federal Aviation Administration

Secor D. Browne
President
Secor Browne Associates

Walter P. Frey
Manager, Technical Service
Aviation Department
Mobil Oil Corporation

James E. Gorham
SRI International

Klaus P. Heiss
President
ECON, Inc.

Milton J. Kittler
Retired President and
Chief Executive Officer
Holley Carburetor Company

James J. Kramer
Manager, Strategic Planning and
Development Operation
Aircraft Engine Group
General Electric Company

James N. Lew
Retired Senior Vice President,
Engineering
Beech Aircraft Corporation

Arthur D. Lewis
President
American Bus Association

Hans W. Liepmann
Director, Graduate
Aeronautical Labs
California Institute of
Technology

Richard J. Linn
Director, Technological
Development
American Airlines

Robert G. Loewy
Institute Professor
Rensselear Polytechnic
Institute

Courtland D. Perkins
President
National Academy of Engineering

Clifton F. von Kann
Retired Senior Vice President
Operations and Airports
Air Transport Association of
America